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CHAPTERS ON THE STARS.

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STATISTICAL STUDIES OF PROPER MOTIONS.

The number of stars now found to have a proper motion is sufficiently great to apply a statistical method to their study. Several important steps in this study have been taken by Kapteyn, who, in several papers published during the past ten years, has shown how conclusions of a striking character may be drawn in this way.

We must begin our subject by showing the geometrical relations of the proper motion of a star, considered as an actuality in space, to the

Fig. 1.

proper motion as we see it. The motion in question is supposed to take place in a straight line, with uniform velocity. Leaving out the rare cases of variations in the motion due to the attraction of a revolving body, there is nothing either in observation or theory to justify us in assuming any deviation from this law of uniformity. The direction of a motion has no relation to the direction from the earth to the star. That is to say, it may make any angle whatever with that direction.

Let E be the position of our solar system, and S that of a star moving in the direction of a straight line, S D. It must not be under-

stood that the length of this line is taken to represent the actual motion; the latter would be infinitesimal as compared with its length; we use it only to show direction. We may, however, use the line to represent on a magnified scale the actual amount of the motion during any unit of time, say, one year. It may be divided into two components; one, S, in the direction of the line of sight from us to the star, which for brevity we shall call the radial line, and the other, S M, at right angles to that line.

It must be understood that, as the term 'proper motion' is commonly used, only the component S M, can be referred to, because the radial component, S R, does not admit of being determined by telescopic vision. As we know from the preceding chapters, it can in the case of the brighter stars be determined by spectroscopic measurement of the radial motion. At present we leave this component out of consideration.

The visible component, S M, can also be resolved into two perpendicular components, the one east and west on the celestial sphere, the other north and south. The former is the proper motion in right ascension (the measured motion in this coordinate being multiplied by the co-sine of the declination to reduce it to a great circle), and the other is the proper motion in declination. In star catalogues these two motions are given, so far as practicable. Thus, altogether the actual motion of a star in space may be resolved into three components: that of right ascension, that of declension, and the radial component.

An additional consideration is now to be added. The proper motion of a star, as observed and given in catalogues, is a motion relative to our system. It has been shown in a former chapter that the latter has a proper motion of its own. When account is taken of this, and the motions are all reduced as well as we can to a common center of gravity of the whole stellar system, we conceive the observed proper motion of the star to be made up of two parts, of which one is the actual motion of the star relative to the common center, and the other due to the motion of the sun, carrying the earth with it. The direction of the latter appears to us opposite that of the motion of the sun. The sun's motion being directed to the constellation Lyra, it follows that the component in question in the case of the stars is directed toward the opposite constellation, Argo. This component, as we know, is termed the parallactic motion, being dependent on the distance or parallax of the star.

As in the case of other proper motions, we may measure the parallactic motion either in angular measure, as so many seconds per century, or in linear measure, as so many kilometers per second. The relation of the two measures depends on the distance of a star. The simplest conception of the relation may be gained by reflecting that the

parallactic motion of a star lying at right angles to the direction of the solar motion during the time that the sun, by its proper motion, is passing over a space equal to the radius of the earth's orbit, is equal to the parallax of the star. For this parallax is simply the angle subtended by that radius as seen from the star; and the same angle is the difference in direction of the star as seen from the two ends of the radius.

As yet, the actual amount of the sun's motion has not been well determined. Kapteyn's estimate is 16.7km. per second, which may be called 10 miles. But the results of additional determinations of radial motions make it likely that this result should be increased to perhaps 19 or 20km. per second, or 4 radii of the earth's orbit per year. Accepting this speed we shall have the following rule:

The parallax of a star lying in a direction nearly at right angles to that of the solar motion is equal to one-fourth of its parallactic motion in a year.

In the case of stars in other directions, the parallax would be greater in proportion to the cosecant of the angle between the direction of the star and the solar apex.

If the stars were at rest this rule would enable us immediately to determine the distance of any star by its proper motion, which would then be simply the parallactic motion itself. Unfortunately, in the case of any one star considered individually, there is no way of deciding how much of its motion is proper to itself and how much is the parallactic motion. But when we consider the great mass of stars, it is possible in a rough way to make a distinction between the two motions in a general average.

The direction or motion of any particular star having no reference to that of the sun is as likely to be in the direction of one of the three components we have described as of any other. Hence, in the average of a great number of stars we may conclude that these components are equal.

One of the simplest applications of this law will enable us to compute the mean parallax of the stars whose radial motions have been determined. As this application is, in the present connection, made only for the purpose of illustration, I shall confine myself to the 47 stars of which the radial motions have been measured by Vogel. The mean annual proper motions of these stars, taken without any regard to their signs, are:

	Including Arcturus.	Omitting Arcturus.
	"	"
In right ascension.....	0.163	0.144
In declination.....	0.155	0.168

The difference of the mean motions in right ascension and

declension is to be regarded as accidental. The velocity of Arcturus is so exceptionally great that we ought, perhaps, to leave it out in taking the mean.

Now, the mean of the radial motions as found by Vogel is 16 kilometers per second. By hypothesis the actual motion in the radial line is in the general average the same as in the other two directions. We have, therefore, to acquire what must be the parallax of a star in order that, moving with a velocity of 16 kilometers per second, its angular proper motion may have one of the above values. This result is by a simple computation found to be:

	″	″
From the mean motion in R. A.	0.049	or 0.043
From the mean motion in Dec.	0.064	or 0.035

The difference of these results shows the amount of uncertainty of the method. Our general conclusion, therefore, is that the mean parallax of the Vogel stars, which may be regarded as corresponding approximately to the mean parallax of all the stars of the second magnitude, is about 0″.04.

We have spoken of the two components of the apparent motion as those in right ascension and declination, respectively. But there is no particular significance in the direction of these coordinates, which have no relation to the heavens at large. For some purposes it will be better to take as the two directions in which the motions are to be resolved that of the parallactic motion and that of right angles to it. That is to say, taking the solar apex as a pole, we conceive a line drawn from it to the star, and resolve the apparent motion upon the celestial sphere into two components, the one in the direction of this line, the other at right angles to it. The former, which we may call the *apical motion*, is affected by the parallactic motion; the latter, which we call the *cross-motion*, is not, and therefore shows the true component of the motion of the star itself in the direction indicated.

Kapteyn has gone through the labor of resolving all the proper motions of the Bradley stars given by Auwers, in this way. His assumed position of the solar apex was:

Right ascension	276°=18h. 24m.
Declination*	+34°

The radically new treatment found in this paper embraces three points. The first consists in the distinction between the spectral types

*This work of Kapteyn is yet unpublished. The author is indebted to his courtesy for the manuscript copy, with permission to use it. Kapteyn's researches based on this material are contained in a paper on the 'Distribution of the Stars in Space,' communicated to the Amsterdam Academy of Science, January 28, 1893. An abstract in English is found in 'Knowledge' for June 1, 1893.

of the different stars and the separate study of the proper motions peculiar to each type. The next point is the reference of the motions to the solar apex. The third is the study of the relations of the stars to the galactic plane.

A remarkable relation existing between the spectral type of stars and their proper motions* was brought out by these investigations. The stars of Type I. have, in the general mean, smaller proper motions than those of Type II. The following table is made up from Kapteyn's work. First we give the limits of proper motion; then on the same line the number of stars of the respective Types I. and II. having proper motions within these limits:

Centennial Prop. motions.	Number of Stars.	
	Type I.	Type II.
0 to 5	786	474
6 to 9	203	194
10 to 19	159	223
20 to 29	25	86
30 to 49	13	71
50 and more	3	58
Total	1,189	1,106

It will be seen that in the case of stars having proper motions of less than 5″ per century a large majority are of Type I. In the case of proper motions between 6″ and 9″ the number is nearly equal. Between 10″ and 20″ there is a large majority of Type II. Between 30″ and 49″ the number of Type II. is nearly five times that of Type I. Finally, only three stars of Type I. have proper motions exceeding 50″, while 58 stars of Type II. have a proper motion exceeding this limit.

We may make two hypotheses on this subject: one, that the stars of Type II. really move more rapidly than those of Type I.; the other, that their actual motion is the same, but that the stars of Type I. are more distant stars. The last conclusion seems much more probable, and is strengthened by the much greater condensation of stars of Type I. toward the Milky Way.

Let us now consider the principles by which we may study a great collection of proper motions statistically. There are scattered around us in the stellar spaces, in every direction from us, a large number of stars, each moving onward in a straight line and in a direction which, with rare exceptions, has nothing in common with the motion of any other star. The velocities of the motion vary from one star to another in a way that can not be determined, some moving slowly and some rapidly. Is it possible from such a maze of motions to determine any-

*The author believes that Monck, of England, independently pointed out this relation, possibly in advance of Kapteyn.

thing? Certainly we can not learn all that we wish, yet we may learn something that will help us form some idea of the respective distances of the stars and the actual velocity of their motions. An obvious remark is that the more distant a star the slower it will seem to move. We must, therefore, distinguish between the linear or actual motion of a star, expressed as so many kilometers per second, and its apparent or angular motion of so many seconds per year, derived by measuring its change of direction as we see it with our instruments.

We shall now endeavor to explain Kapteyn's method in such a way that the reasoning shall be clear without repeating the algebraic operations which it involves. Let us conceive that Fig. 2 is drawn on the celestial sphere as we look up at the heavens. S is the direction of a star in the sky as we see it. Let us also suppose that the solar apex, situated in the constellation Lyra, lies anywhere horizontally to the left of the star, in the direction of the arrow-head marked *Apex*. Sup-

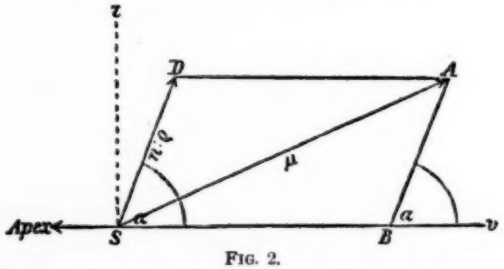

FIG. 2.

pose also that, were the solar system at rest, we should see the star moving along the line S D. Let the length of the line S D represent the motion in some unit of time, say, one year. Next, suppose the star at rest. Then in consequence of the motion of the solar system, by which we are carried toward the apex, the star would seem to be moving with its parallactic motion in the direction S B, away from the apex. Let the length of this line represent the parallactic motion in one year. Then by the theory of composition of motions, the star moving by its real motion from S to D, and by the motion of the earth having an apparent motion from S to B, will appear to us to move along the diagonal S A of the parallelogram. Thus, the line S A will represent the annual proper motion of the star as we observe it with our instruments, and which can be resolved into the apical motion, in the direction S B, and is cross-motion in the direction Sτ.

The apical motion consists of two parts, one the parallactic motion, equal to S B; the other real, and due to the motion of the star itself along the line S D, and equal to the distance of D from the line Sτ.

We have now to inquire how, in the case of a great number of stars, we may distinguish between the two parts.

We now make the general hypothesis that, in the average of a great number of stars, actual motions have no relation to the direction of our sun from the star. Then the components of the actual motion, S D, will in the general average have equal values, positive and negative canceling each other. Hence, if we take the mean of a great number of motions along the apical line it will give us the value of S B due to the motion of the earth, and, hence, the mean parallactic motion of all the stars considered.

The problem now becomes one of averages. We wish to form at least a rude estimate of the average speed of a star in miles or kilometers per second. To show how this may be done let us suppose that we observe the proper motions of a great number of stars at some distance from the solar apex, so that their parallactic motion shall be observable. Stumpe and Ristenpart, the German astronomers, as well as Kapteyn, have considered the relation between the two motions in the following way: We divide the stars observed into classes, taking, say, one class having small, but easily measured, proper motion; another having a proper motion near the average, and a third, of large proper motion. Sometimes a fourth class is added, consisting of stars having exceptionally large proper motions. From each of these classes we can determine, as already shown, the average motion from the direction of the solar apex; that is to say, the average parallactic motion. This will be inversely as the average distance of the stars.

Stumpe's three classes were: I., proper motions ranging from 16″ to 32″ per century; II., between 32″ and 64″ per century; III., between 64″ and 128″ per century; IV., greater than 128″. The average of the proper motions in each class, the average of the parallactic motions and the ratio of the two are these:

Class.	Prop. Mot. ″	Par. Mot. ″	Quotient.
I.	0.23	0.142	1.6
II.	0.43	0.286	1.5
III.	0.85	0.583	1.4
IV.	2.39	2.057	1.1

It will be seen that the ratio of the proper motion of the star to the parallactic motion diminishes as the former increases.

The same thing was found by Ristenpart from the proper motions of the Berlin zone, as shown below:

Class.	Prop. Mot. ″	Par. Mot. ″	Quotient.
Small	0.128	0.061	2.1
Medium	0.197	0.109	1.8
Large	0.374	0.279	1.3

The smaller value of the quotient from stars near to us

than from the more distant stars was supposed to lead to the conclusion that the latter had a more rapid real motion than the former. A little thought will show that, while this is quite true of the stars included in the list, this does not prove it to be true for the stars in general. We can not, as already pointed out, determine the motion of any star unless it exceeds a certain limit. Hence, in the case of the more distant stars we can observe the proper motions only of those which move most rapidly, while in the case of the nearer ones we may have measured them all. We should, therefore, naturally expect that the more distant stars in our list will show too large a value of the proper motion, for the simple reason that those having small proper motion are not included in the average. There is, therefore, no evidence that the more distant stars move faster than the nearer ones.

An error in the opposite direction occurs through the method of selecting stars of given proper motion. We have already pointed out that in the case of any individual star we cannot determine how much of its apparent apical motion may be that of the star itself, and how much the parallactic motion arising from the motion of the earth. What we have done is to assume that in the case of a great number of stars the actual apical motions will be equal, and in the opposite directions, so as to cancel each other in the average of a great number, leaving this average as the parallactic motion. Now, to fix the ideas, suppose that two stars have an equal apical motion, say 3 radii of the earth's orbit in a year, but in opposite directions. The apical motion of the earth being 4 radii per year, it follows that the star which is moving in the same direction as the earth will have a relative apical motion of only 1, and will, therefore, not appear in our list as a star of large proper motion. On the other hand, the star moving with equal speed in the opposite direction will have a motion of 7 radii per year, and, will, therefore, be included among stars of considerable proper motion. Thus, a bias occurs, in consequence of which we include many stars having a motion away from the solar apex, while the corresponding ones, necessary to cancel that motion, will be left out of the count. Thus, the parallactic motion will, in the average, be too large in the case of the stars of large apparent proper motion. Now, this is exactly what we see in the above tables. As we take the classes with larger and larger proper motions, the supposed parallactic motion, which is really the mean of the apical motions, seems to increase in a yet larger degree. It is, therefore, impossible to determine from comparisons like these what the exact ratio is.

This error is avoided when we do not arrange and select the stars according to the magnitude of their proper motions, but take a large list of stars, determine their proper motions as best we can and draw our conclusions from the whole mass. This has been done by Kapteyn

in the paper already quoted; and by a process too intricate to be detailed in the present work he has reached certain conclusions as to the ratio of the actual motion of the sun in space to the average motion of the stars. His definitive result is:

Average speed of a star in space
= Speed of solar motion × 1.86.

This I shall call the straight-ahead motion of the star, without regard to its direction. But the actual motion as we see it is the straight-ahead motion, projected on the celestial sphere. The two will be equal only in cases where there is no radial motion to or from the earth. In all other cases the motion which we observe will be less than the straight-ahead motion. By the process of averaging, Kapteyn finds:

Linear projected speed of a star
= Speed of solar motion × 1.46.

This projected motion, again, may be resolved into two components at right angles to each other. It follows that the average value of either component will be less than that of the projected motion. The components may be the motions in right ascension or declination, or the apical motion and the motion at right angles to it. In any case, the mean value of a component will be:

Speed of solar motion × 0.93.

I have used Kapteyn's numbers to obtain the same relation by a somewhat different and purely statistical method.

Imagine the proper motion of a star situated nearly at right angles to the direction of the solar motion. Although we cannot determine how much of its apical motion is actual and how much is parallactic, we can determine whether its motion, if toward the solar apex, exceeds that of the sun. In fact, all stars the apical component of whose motion is in the same direction and greater than that of the sun, whatever the distance of the star, appear to us as moving toward the apex, a direction to which we assign a negative algebraic sign. All stars moving more slowly than this, or in the opposite direction from the sun, will have apparent motions away from the apex, which we regard as algebraic positive. We can, therefore, by a simple count separate the stars moving in the same direction as the sun, and with greater speed, from all the others.

I have classified the stars in this way not only as a whole, but also with reference to their cross-motion—motion at right angles to that of the sun. That is to say, I have taken the stars whose cross-motion, τ, is 2″ per century or less and counted their apical motions as positive, negative and zero. Then, I have done the same thing with cross-motions of 3″ or 4″, then with cross-motions ranging from 5″ to 7″, and

so on. All cross-motions above 13″ we put together.* The results of this work are shown, so far as described, in the first four columns of the table below. We have here for the various values of τ the number of positive, negative and zero apical motions.

Table showing the number of positive and negative apical motions for different values of the cross-motion.

Values of τ	Special Motions, σ					Percentage.	
	Pos.	Zero.	Neg.	P′.	N.	N.	P.
0, ± 1, 2.....	1,013	261	425	1,143	555	0.33	0.67
± 3, 4.....	360	56	160	388	188	0.33	0.67
± 5 to 7.....	285	37	107	303	125	0.29	0.71
± 8 to 12.....	215	7	52	218	55	0.20	0.80
± 13 +.....	216	2	61	217	62	0.22	0.78
Total.....	2,089	363	805	2,269	985	0.30	0.70

The first question that arises in connection with this table is how to count the motions that come out zero; that is to say, those which are too small to be certainly observed. The most probable distribution we can make of them is to suppose that they are equally divided between positive and negative motions. I have, therefore, added one-half of the zero motions to the positive and one-half to the negative column, thus getting the results given in columns P and N. The percentages of positive and negative motions thus resulting are given in the last column.

We see that there is a fairly regular progression in the percentage, depending on the value of the cross-motion. In the case of the small cross-motions, which presumably belong to the more distant stars, the percentage of negative motions is markedly greater than it is in the case of the nearer stars which have larger values of τ. The diminution in the number of zero motions is still more remarkable. This arises from the fact that in the case of the nearer stars the apical motions are necessarily larger, whether positive or negative.

In the preceding table all the stars were counted, without reference to their distance from the solar apex. The result of this will be that the mean of the apical motions is taken as we see it projected on the sphere, which does not correspond to the actual motion in space except when the direction of the star is at right angles to that of the apex. I have, therefore, made a second partial count, including only stars between 60° and 120° from the apex. These stars were selected in oppo-

*The author should say that the greater part of the work on these countings was done with great care and accuracy by Mrs. Arthur Brown Davis, to whom he is so much indebted for help of this kind through the present work.

site regions of the heavens, so as to eliminate any constant error depending on the right ascension. The result of a count of 733 stars is:

Number of positive motions	530
" " zero "	50
" " negative "	153

If we proceed as before, dividing the zero motions equally between the positive and negative ones, we shall find the respective numbers to be 555 and 178. The percentage of negative motions is, therefore, 24. This will still be slightly too large, owing to the obliquity under which many of the stars were seen. We may estimate the most likely percentage as 23.

We conclude, therefore, that when the motions of all the stars are so resolved that one component shall be that in the direction of the apex, 23 per cent. of the stars will be found moving toward the apex with a greater speed than that of the sun. It may, therefore, be assumed that in the general average an equal number are moving in the opposite direction with a greater speed than that of the sun. We conclude, therefore, that the resolved motion of 46 of the stars is greater than of the sun, leaving 54 per cent. less.

In the absence of an exact knowledge of the relation between the magnitude and the number of motions, we shall not be far wrong in assuming that one-half the stars move to or from the apex with more than the average speed, and one-half with less. Comparing this with the percentage found, we may conclude that the average motion of a star is less than that of the sun, in the ratio 46:50; or that it is found by multiplying the motion of the sun by the factor 0.92. This is almost exactly the number which we have quoted from Kapteyn.

We have already stated that the actual speed of the solar motion, still somewhat uncertain, may be estimated at 20 kilometers per second, or 4 radii of the earth's orbit in a year. For our present purposes the latter method of expressing the velocity is the more convenient. Multiplying this speed by the factors already found, we have the following results for the average proper motions of a star in space expressed in kilometers per second, and radii of the earth's orbit in a year:

Straight-ahead motion	37km. = 7.4r.
Projected motion	29km. = 5.8r.
Motion in one component	19km. = 3.7r.

The motion of 20km. or 4r. assigned to the sun is its straight-ahead motion. This is little more than half the average. It follows that our sun is a star of quite small proper motion.

THE DISTRIBUTION OF THE STARS IN SPACE.

We shall now bring the lines of thought which we have set forth in the preceding chapters to converge on our main and concluding problem, that of the distribution of the stars in space. While we cannot

reach a conclusion that can claim numerical exactness, we may reach one that will give us a general idea of the subject. The first question at which we aim is that of the number of stars within some limit of distance. It is as if, looking around upon an extensive landscape in an inhabited country, we wished to estimate the average number of houses in a square mile. On the general average, what is the radius of the sphere occupied by a single star? If we divide the number of cubic miles in some immense region of the heavens by the number of stars within that region, what quotient should we get? Of course, cubic miles are not our unit of measure in such a case. It will be more convenient to take as our unit of volume a sphere of such radius that from its center, supposed to be at the sun, the annual parallax of a star on the surface would be 1″. The radius of this sphere would be 206,265 times that of the earth's orbit. We may use round numbers, consider it 200,000 of these radii, and designate it by the letter R.

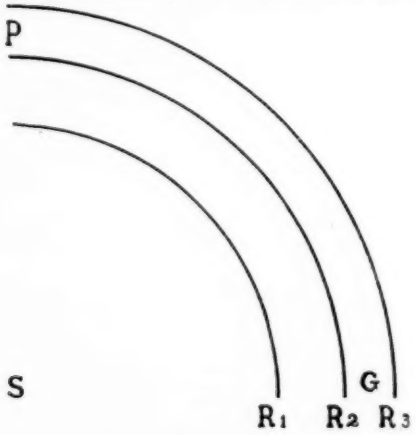

FIG. 3.

Now, let us conceive drawn around the sun as a center concentric spheres of which the radii are R, 2R, 3R, and so on. At the surfaces of these respective spheres the parallax of a star would be 1″, half a second, one-third of a second, and so on. The volumes of spheres being as the cubes of their radii, those of the successive spheres would be proportional to the numbers 1, 8, 27, 64, etc.

If the stars are uniformly scattered through space, the numbers having parallaxes between the corresponding limits will be in the same proportion.

The most obvious method of determining the number of stars within the celestial spaces around us is by measurement of their parallaxes. It is possible to reach a definite conclusion in this way only in the case of parallaxes sufficiently large to be measured with an approach to accuracy. In the case of a small parallax the uncertainty

of the latter may be equal to its whole amount. In this case the star may be at any distance outside the sphere given by its measured parallax, or far within that sphere, so that no conclusion can be drawn. It is, on the whole, useless to consider parallaxes less than 0″.10; even those having this value are quite uncertain in most of the cases. The data at command for our purpose are the known individual parallaxes and the statistical summary given by Dr. Chase as the result of his survey, and quoted in our chapter on the parallaxes of the stars. This survey was confined to stars whose parallax was not already measured, and it brought out no parallax exceeding 0″.30.

The most careful search has failed to reveal any star with a parallax as great as 1″, and it is not likely that any such exists. It is, therefore, highly probable that the first sphere will not contain a single star except the sun in its center.

Within the third sphere, the parallax at the surface of which is 0″.33, we may place the following for stars with entire certainty:

α Centauri	Par.=0.75
Ll. 21,185	0.46
61 Cygni	0.39
Sirius	0.37

There are two other cases in which the parallax is doubtful, though the measures as made bring the stars within the sphere 3R. They are:

η Herculis	Par.—0.40
O. A. 18,609	0.35

In the case of η Herculis the proper motion is so small that the presumption is strongly against so large a parallax, and the doubtful parallax of the last star is so near the limit that it may be left out of the count. The doubt in its case may be set off against a doubt whether the parallax assigned to Ll. 221,185 is not too large. We assume, therefore, that four stars are contained within the sphere 3R, the volume of which is $3^3 = 27$. This would give, in whole numbers, one star to 7 unit spheres of space.

When we come to smaller parallaxes we find a great deficiency in the number measured in the Southern hemisphere. The policy of Gill, under whose direction or with whose support all the good measures in that hemisphere were made, was to make a few very thorough determinations rather than a general survey. Between the limits 0″.20 and 0″.33 are found:

In the Southern Hemisphere	4 meas.	(Gill)
" Northern "	2 "	(Chase)
" " "	12 "	(Others)
Total	18	

Of the Northern results three are exactly on the limit, 0″.20, and several others are doubtful, and probably too large. The most likely number for the Northern hemisphere seems to be 12, and if we estimate an equal number for the Southern hemisphere we shall have 24 in all. Adding the four stars within the sphere 3R, we shall then have a total of 28 within the sphere 5R, of which the volume is 125. This gives between 4 and 5 space units to a star.

Let us now consider the space between the spheres 5R and 10R, including all stars whose parallax lies between the limits 0″.10 and 0″.20. Of these the numbers are:

Southern Hemisphere.....	6 (Gill)
Northern "	15 (Chase)
" "	15 (Others)

Reasoning as before, we may assume that the number of stars between the assigned limits is 60, making a total of 88 within the sphere 10R. The volume of space enclosed being 1,000 units, this will give one star to 12 units of space.

How far can we rely on this number as an approximation to the actual number of stars within the tenth sphere? The errors in the estimate are of two classes, those affecting the parallax itself and those arising from a failure to include all the stars within the sphere. The very best determinations are liable to errors of two or three hundredths of a second, the inferior ones to still larger errors. Thus, it may happen that there are stars with a real parallax larger than the limit of which the measures fall below it and are not included, and others smaller than the limit which, through the errors of measurement, are made to come within the sphere. As we have seen in the chapter on the parallaxes, it is quite possible that there may be a number of stars with a measurable parallax whose proximity we have never suspected on account of the smallness of the proper motion. We can only say that the nearer a star is to the system the more likely its proximity is to be detected, so that we are much surer of the completeness of our list of large parallaxes than of small ones. Hence, there may well be a number of undetermined parallaxes upon or just above the limit 0″.10.

The most likely conclusion we can draw from this examination seems to be that in the region around us there is one star to every 8 units of space; or that a sphere of radius, 2R, equal to 412,500 radii of the earth's orbit, corresponding to a parallax of 0″.50, contains one star. This is a distance over which light would pass in 8½ years.

We next see how far a similar result can be derived from statistics of the proper motions. It seems quite likely that nearly all proper motions exceeding 1″ annually have been detected. The number known is between 90 and 100, but it can not be more exactly stated because there is some doubt in the case of a number which seem to

be just about on the limit. In this value, 1″, is included the effect of the parallactic motion, which, on the general average, increases the apparent proper motion of a star. To study this effect let us call the list of 90 or more stars actually found List A. Were it possible to observe the proper motions of the stars themselves separate from the parallactic motion, we should find that, when we enumerate all having a proper motion of more than 1″, we should add some to our List A and take away others. The stars we should add would be those moving in the same direction as the sun, whose motions appear to us to be smaller than they really are, while we should take away those moving in the opposite direction, whose motions appear to us larger than they really are. On the average, we should take away more than we added, thus diminishing slightly the number of stars whose motion exceeds 1″. Making every allowance, we may estimate that probably 80 stars have an actual proper motion on the celestial sphere of 1″ or more. We have found that the average linear proper motion of a star, as projected on the sphere, is about 6 radii of the earth's orbit annually. A star having this motion would have to be placed at the distance 6R to have, as seen by us, an angular motion of 1″. The parallax corresponding to the surface of this sphere is 0″.167. The volume of the sphere is 216, and according to our estimate from the parallaxes it would contain only 27 stars. It will be seen that these results give a greater density of the stars than the result from the measured parallaxes; that is to say, they indicate that there are still an important number of measurable parallaxes to be determined, while the number of stars is less than would be derived from their proper motions. But the fact is that the number of stars estimated as within a given sphere by the proper motions will be in excess, owing to the actual diversity of these proper motions, which may range from 0 to a value several times greater than the average. In consequence of this, our list of stars with a proper motion exceeding 1″ will contain a number lying outside the sphere 6R, but having a proper motion larger than the average. We are also to consider that within the sphere may actually lie stars having a proper motion less than the average, which will, therefore, be omitted from the list. Of the number of omitted and added stars the latter will be the greater, because the volumes of spheres increase as the cubes of their radii. For example, the space between the spheres 6R and 9R is more than double that within 6R, and our list will include many stars in this space. The discrepancy between the parallaxes and the proper motions probably arises in this way.

Let us see what the result is when we take stars of smaller proper motion. The most definite limit which we can set is 10″ per century. We have seen that Dr. Auwers, in his zone, found 23.9

stars per 100 square degrees having a proper motion of 10″ or more. This ratio would give about 10,000 for the whole heavens. The sphere corresponding to this limit of proper motion is 60R. On our hypothesis as to star density this sphere would contain 27,000 stars, nearly three times the number derived from Auwers's work. But it is not at all unlikely that even this sphere in question contains twice as many stars as have been detected. Great numbers of the more distant stars will not have been catalogued, owing to their faintness, because a star at the distance 60R will shine to us with only one per cent. the light of one at distance 6R. This corresponds to a diminution of five magnitudes; that is to say, a star of the sixth magnitude at distance 6R would only be of the eleventh magnitude at distance 60R, and would, therefore, not be catalogued at all. There is, therefore, no reason for changing our estimate of star density, which assigns to each star around us 8 units of volume in space.

This fact suggests another important one. Owing to the great diversity in the absolute magnitude of the stars, those we can observe with our telescopes will naturally be more crowded in the neighborhood of our system than they will at greater distances.

Some further results as to the mean parallax of the stars may be derived from a continuation of the statistical study of the proper motions. Kapteyn's investigation in this direction includes a determination of the mean parallactic motion of the stars of each magnitude for the first and second spectral types separately. From this he obtains the following mean parallaxes for stars of the different magnitudes:

Mean parallaxes of stars of different magnitudes, and of the two principal types, as found from their parallactic motions:

Mag.	Type I.	Type II.
	″	″
2.0	.0315	.0715
3.0	.0223	.0515
4.0	.0157	.0357
5.0	.0111	.0253
6.0	.0079	.0179
7.0	.0056	.0126
8.0	.0039	.0089
9.0	.0028	.0063
10.0	.0020	.0045
11.0	.0014	.0032

Using the value 4 for the solar motion, instead of 3.5, found by Kapteyn, all these parallaxes should be diminished by one-eighth of their amount.

Unfortunately, owing to the great diversity in the absolute brightness of the stars, and the resulting great difference in the distances of stars having the same magnitude, these numbers can give us only

a vague idea of the actual parallaxes. Let us take, for example, the stars of the sixth magnitude. A few of these are, doubtless, quite near to us and have a parallax several times greater than that of the table. Excluding these from the mean, an important fraction of the remainder will have a parallax much smaller than that of the table.

We get a slightly more definite result by studying another feature of the proper motions. We may consider the Bradley stars, whose motions have been investigated, as typical, in the general average, of stars of the sixth magnitude. By a process of reasoning from the statistics, of which I need not go into the details at present, it is shown that the parallactic motion of a large number of these stars, probably one-eighth of the whole, is about 1″ per century or less. To this motion corresponds a parallax of 0″.0025, corresponding to the sphere of radius 400R.

The statistics of cross-motions lead to a similar conclusion. One-half the Bradley stars have a cross-motion of less than 2″.5 per century. To this motion would correspond a sphere of radius 200R and a parallax of 0″.005. Stars at this distance must be hundreds of times the absolute brightness of the sun to be seen as of the sixth magnitude. Yet the conclusion seems unavoidable that the sphere of lucid stars extends much beyond 400R.

Granting the star density we have supposed, a sphere of radius 400R would contain 8,000,000 stars. As we see many more than this number with the telescope, we have no reason to suppose the boundary of the stellar system, if boundary it has, to be anywhere near this limit.

All the facts we have collected lead to the belief that, out to a certain distance, the stars are scattered without any great and well-marked deviation from uniformity. But the phenomena of the Milky Way show that there is a distance at which this ceases to be true. Let S be the sun, R a portion of the surface of the outer sphere of uniform distribution, and R2 and R3 two contiguous spheres passing through the galactic region G, of which the pole is in the direction P. It is quite certain that the star-density is greater around G than around P. This may arise either from the density at G being greater, or from that at P being less, than the density within the sphere R. From the enormous number of stars collected in the galactic regions, we can scarcely doubt that the former alternative is the correct one. But there must be a sphere at which the second alternative is also correct, because we find the number of stars, even of the lucid ones, to continuously increase from P toward G.

Can we form any idea where this difference begins, or what is the nearest sphere which will contain an important number of galactic stars? A precise idea, no; a vague one, yes. We have seen that the galactic agglomerations contain quite a number of lucid stars, and

that, perhaps, an eighth of these stars are outside the sphere 400R. We may, therefore, infer that the Milky Way stars lie not immensely outside this sphere. More than this, it does not seem possible to say at present.

So far as we can judge from the enumeration of the stars in all directions, and from the aspect of the Milky Way, our system is near the center of the stellar universe. That we are in the galactic plane itself seems to be shown in two ways: (1) the equality in the counts of stars on the two sides of this plane all the way to its poles, and (2) the fact that the central line of the galaxy is a great circle, which would not be the case if we viewed it from one side of its central plane.

Our situation in the center of the galactic circle, if circle it be, is less easily established, because of the irregularities of the Milky Way. The openings we have described in its structure, and the smaller density of the stars in the region of the constellation Aquila, may well lead us to suppose that we are perhaps markedly nearer to this region of its center than to the opposite region; but this needs to be established by further evidence. Not until the charts of the international photographic survey of the heavens are carefully studied does it seem possible to reach a more definite conclusion than this.

One reflection may occur to the thinking reader as he sees these reasons for deeming our position in the universe to be a central one. Ptolemy showed by evidence which, from his standpoint, looked as sound as that which we have cited, that the earth was fixed in the center of the universe. May we not be the victims of some fallacy as he was?

THE LAW OF SUBSTANCE.

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IN Haeckel's new and remarkable monistic book, 'The Riddle of the Universe at the Close of the Nineteenth Century,' which has just been translated by Joseph McCabe and published by the Harpers, the accepted laws of the persistence of matter and the persistence of energy are enunciated and their unity insisted upon; the union constituting what is denominated 'The Law of Substance.' Substance, 'Stoff,' in other words, being in fact what we are familiar with as matter, including all its physical attributes, as essential parts of it, as a person's character and his material parts are one and, failing either of those attributes, is no longer the same. It is only by these characteristics that we can recognize or define either the person or the molecule; without them, so far as we can see, there would be neither person nor matter.

The principle and the law of substance are unquestionably now incorporated into the scientific code permanently and positively; but the time of recognition and the dates of discovery of the two elements of that law are not, in the opinion of the writer, precisely as stated by Haeckel; the discoverers are not given credit by this author in correct proportion. He accords to Lavoisier the discovery of the persistence of matter and the proof of that principle, undoubtedly, as generally believed, correctly. He gives Robert Mayer (1842) credit for the discovery of the principle of the persistence of energy and assigns to Helmholtz (1847) its more general application.

It was, in fact, Benjamin Thompson (Count Rumford), the American philosopher, who, in 1796-97, experimentally proved the equivalence of the two forms of energy, thermal and dynamic. He read the paper describing his work in 1798, before the Royal Society of Great Britain; while Sir Humphry Davy confirmed it and added further proof immediately afterward.

It must be carefully noted that there are at least three quantities to be observed, studied and quantitatively measured: (1) substance or matter; (2) the forces which affect matter; (3) energy. Matter can perhaps be conceived of as destitute of any designated force and possibly even of any known attributes, such as the physical forces; forces can possibly be conceived apart from any specific matter; energy involves both matter and motion, and infers the action of forces in its production or variation. Nevertheless, our only method of acquiring a knowledge of mat-

ter is through the action of its attribute forces upon our senses; it is indeed possible that matter only exists through that quality which makes it the residence of the physical forces; it is extremely probable that all natural forces affect all matter and originate in matter.

There are just three corollaries to the general 'Law of Substance,' the Law of Persistence of all Existences; these are:

1. The Law of the Persistence of Matter *per se*.
2. The Law of Persistence of Force as an Attribute of Matter.
3. The Law of Persistence of Energy, whether as affecting a mass of matter or in process of transfer or of transformation; affecting varying quantities and kinds of matter; passing from one quantity of matter to another; changing, in inverse direction, the quantity of matter affected and the velocity-component of the energy; the product of mass and mean velocity-square remaining constant for the whole universe.

The distinction between force and energy was not, in earlier times, very exactly observed; but it is easy to perceive in the context to the enunciation of either corollary to the fundamental law the fact that writers usually well understood the principle which they sought to state. It had, by Faraday's time, come to be well understood by many scientific men that matter is persistent, that its characteristic forces cling to it persistently and that energy is the product of forces and motion, and is consequent upon inertia.

The writer took occasion, in a paper read before the American Society of Civil Engineers (December 9, 1873), criticizing Professor Tait's 'Sketch of Thermodynamics,' his assignment to Sir Humphry Davy of a prior place and his depreciation of the work of Mayer, to show that Rumford is entitled to a larger credit than is ordinarily assigned him even by those who admit his first appearance in this line of investigation at the close of the eighteenth century. It is easy to show that, not only was Rumford the first to exhibit by experimental research the fact of the equivalence of thermal and dynamic energy, but that he was the first to establish with some degree of approximation their quantivalence. In fact, he secured data giving a much closer determination of the 'mechanical equivalent of heat' than did Joule, or any other investigator of later years up to the middle of the century; at which date, while an approximate value had been hit upon, so great was the variety of constants published that the real value was still exceedingly uncertain. Professor Tait, however, was the first to call attention to the fact that Rumford actually gave data sufficient to afford a basis for computation of the equivalent, but he made the resultant figure 940 foot-pounds, assuming the horse-power at 33,000 foot-pounds per minute, and failing to note the fact that the engineer's 'horse-power' is considerably larger than the power of the average horse.

Taking the generally accepted and fair mean value for the power of

the animal, and accepting Rumford's statement that the work was that which could be readily performed 'by a single horse,' the writer showed that the quantity of heat developed in Rumford's experiments, compared with the accepted datum, 25,920 foot-pounds per minute as the power of the horse, as given by Rankine, for the average case, or better, say 25,000 for the average Bavarian horse of the last century, we obtain as the 'mechanical equivalent,' 783.8 foot-pounds, differing from 778, the accepted figure of Rowland and later authorities, by but six units, less than 1 per cent. of its own value and vastly nearer than any figures obtained up to our own time.

Thus, as the writer claimed in 1873, we may state the achievement of that great philosopher and engineer in the following terms:

1. Rumford was the first to prove experimentally the immateriality of heat.

2. He was the first to indicate and directly to prove it to be a form of energy; publishing his proof a year before Davy.

3. Rumford first, a half-century before Joule, determined by experimental research the quantivalence of thermal and dynamic energies, and secured data giving the value of the factor of equivalence with almost perfect accuracy.

4. He is entitled to the sole credit of the experimental discovery of the true nature of heat, of its equivalence with mechanical energy and its measure of quantivalence.

The work of Sir Humphry Davy was of great importance; but it was in confirmation of the deductions previously announced to the Royal Society by his contemporary and colleague, Rumford.

"Benjamin Thompson, of Concord, New Hampshire, commonly known as Count Rumford, the Bavarian, should be accorded a higher position and a nobler distinction than has yet been given him by writers on thermodynamics."*

Rumford, above all others, ancient or modern, is entitled to the credit of not only laying down an experimental foundation for the 'Law of Substance' and the principle of persistence of energy, but also for actually making it a physical, rather than as previously a metaphysical, topic; for proving the falsity of the older views of the nature and origin of heat in thermodynamic systems, for proving by direct test and experimental investigation the immateriality of heat and its real character as a 'mode of motion,' as Tyndall called it, as a form of energy more properly. He furnished a method and means of estimating the 'mechanical equivalent of heat'; he originated by actual work of research a true statement of the principle of the quantivalence of the two forms of

* Transactions of the American Society of Civil Engineers, 1873. 'Note relating to Rumford's Determination of the Mechanical Equivalent of Heat.'—Thurston.

energy and, inferentially, of the quantivalent relations of all energies. He originated the now usual method of determining the quantivalence of heat and thermal and dynamical forms of energy by the storage of the heat of friction in a mass of water, and, by the churning of liquids, of similarly storing the heat of fluid-friction. He adopted the view that the energy developed in the animal system is the measure of a certain proportion of the stored energy of the food thus utilized. Thus he extended the principle of persistence to the organic world and to living creatures, opening the way to the final generalizations and conclusions of the enunciator of the so-called 'Law of Substance.'

Thus Rumford was the first to prove by experimental investigation the transformability of the energies, to exhibit the principle in its most important example and to derive, by physical research, the principle of the thermodynamic equivalence of energies and the fact of heat being simply a form of energy and a mode of motion of substance.

Mayer seems to have been the first to recognize a now well-understood fact: that, if we are to gain a more effective development of the energies, potential in our fuels, which are practically our only sources of commercially useful energy, we must find a way to transform the potential energy of chemical union directly into some other form than the thermal and by some other than the thermodynamic process. He says* that 'the evident wastes of the thermodynamic process as illustrated in our best steam engines justify us in seeking other methods of energy-transformation,' more particularly by the transformation into motion of electricity obtained by chemical means.

Mayer was probably the first to write under the definite title 'The Mechanical Equivalent of Heat.'† He was the first to declare, in so many words: 'the *vis viva* of the universe is a constant quantity.'‡ He stated that 'the heat produced mechanically by the organism must bear an invariable quantitative relation to the work expended in producing it.'

This he deduced from his 'physiological theory of combustion.' He anticipates the idea of the permanence of the universe in its present general aspect by the suggestion that this redistribution of energy, 'degraded' by other phenomena, may be effected 'by the falling together of previously invisible double stars' or equivalent phenomena.§ He finds by computation that the energy transformed through such collisions 'would considerably exceed that which an equal weight of matter could furnish by the most intense process of chemical action'—in other words: it would resolve the solid mass into its elementary atoms; which is pre-

*'Forces of Inorganic Nature; 'Liebig's Journal,' 1842.

†'The Mechanical Equivalent of Heat,' 1851.

‡'Celestial Dynamics,' 1848.

§'The Mechanical Equivalent of Heat,' 1851.

cisely the idea now held by Haeckel and other contemporary men of science.

Mayer accepted the principle and, basing his computations on the then accepted values of the specific heat of air, determined an equally approximate mechanical equivalent. Joule followed, in 1845-49, and later, determining this equivalent by admirable direct experiment. English writers have sometimes insisted upon assigning all credit to the latter for this determination; but Tyndall is less insular in his attitude and frankly and cordially gives Mayer the credit to which he is undoubtedly entitled. Both are certainly to be credited with important original work, and the method of Mayer gives a more accurate and certain measure of the constant sought than did any of the earlier experiments of the English physicist, the more exact measures of specific heats as now known being employed. Had Mayer known of Regnault's work, or had that work been completed before Mayer attempted his computations, the latter would have obtained more accurate figures than Joule secured years afterward. It was only when Prof. Henry A. Rowland took up the task and performed his marvelously fine work that an acceptable valuation was secured.

Meantime, Helmholtz had accepted and applied the law of equivalence of the energies broadly, as holding in all physical phenomena; but he was distinctly anticipated by Grove, the English physicist, who in January, 1842, in a lecture before the London Institution, asserted that 'Heat, light, electricity, magnetism, motion and chemical affinity are all convertible material affections' and that 'all these affections are resolvable into one, namely motion.'* This thesis he enforced then and thenceforward continuously. In 1862, he summarized his work in a published study of 'The Correlation of the Physical Forces,' later reprinted by Youmans in his famous collection of similar papers of 1864. His paper concludes with an excellent bibliography, in which he shows the origin of the now unquestioned view of authority in the minds of the old Greeks, and its gradual establishment by observation, experience and, finally, by experiment in the nineteenth century.

Helmholtz's lecture 'On the Interaction of the Natural Forces' was delivered at Königsburg, in 1854; he at the time holding the professorship of physiology at that university. In this lecture he states his first ideas to have been published in a pamphlet, in 1847, 'On the Conserva-

* Perhaps the best presentation of the work of the earlier men of science, recognizing these great and fundamental truths, is that of Prof. Edward L. Youmans, the founder of the POPULAR SCIENCE MONTHLY and one of the most broad-minded and far-seeing men of his time, who, in his 'Correlation and Conservation of Forces,' published by the Appletons in 1865, brought together the records of the great pioneers in this evolution of the scientific basis of all natural science, including the papers of Grove, Helmholtz, Mayer, Faraday, Liebig and Carpenter.

tion of Force,'* in which he 'endeavored to ascertain all the relations between the different natural processes.' In his lecture of 1854, he credits earlier writers on the subject, in the following order: Carnot (1824), Mayer (1842), Colding (1843), Joule (1843), and states that he was awakened to this work by the last-named.

To the Carnot law, Helmholtz gives the following expression: 'Heat only when passing from a warmer to a colder body, and then only partially, can be converted into mechanical work.'

This is obviously no other than the essence of the principle as not only asserted, but actually proved, a quarter of a century before Carnot by Benjamin Thompson and Humphry Davy, by direct experiment, so far as it is an assertion of the convertibility of the two energies. Helmholtz acknowledges the indebtedness of the scientific world to Mayer, whose paper 'On the Forces of Inorganic Nature' had been printed in 1842, that 'On Organic Motion and Nutrition' in 1845, and that 'On Celestial Dynamics' in 1848; while his paper 'On the Mechanical Equivalent of Heat' was not published until 1851.†

Helmholtz concludes: 'Thus the thread which was spun in darkness by those who sought a perpetual motion has conducted us to a universal law of nature which radiates light into the distant nights of the beginning and to the end of the history of the universe.'

Dr. W. B. Carpenter, in a lecture before the Royal Society, published later in their Transactions for 1851, summarized the work in this field, to his date, under the title 'The Correlation of the Vital and Physical Forces,' and showed, probably for the first time in this field, the unity of the principle of equivalence of energies in organic and vital, as well as in inorganic and lifeless nature. He attributes to Dr. Mayer, of Heilbronn, the first annunciation of the great principle of 'Conservation of Force,' in its then broadest form, in his paper of 1845, already mentioned; while Carpenter considers his own paper of 1850 'On the Mutual Relations of the Vital Physical Forces, as the first announcement of the extension of the law beyond the latter class of phenomena into the range of vital energies. It is in his lecture on this subject that Carpenter states the fact, since recognized perhaps most explicitly, among contemporary writers, by Haeckel, that 'what the *germ* supplies is not the force but the *directive agency*.' 'The actual constructive force is supplied by heat.' Even 'the life of man, of any of the higher animals, consists in the manifestation of forces of various kinds, of which the organism is the instrument,' and, further: ' during the whole life of the animal, the organism is restoring to the world around it both the *materials* and the *forces* which it draws from it.'

* It will be noted that it was very usual among these earlier writers to employ 'force' synonymously with 'energy,' as we now define the latter.

†All these papers may be found in Youman's collection, already alluded to.

"But there is this marked contrast between the two kingdoms of organic nature in their material and dynamic relations to the inorganic world: that while the vegetable is constantly engaged in raising its component materials from a lower plane to the higher, the animal, whilst raising one portion of these to a still higher level by the descent of another portion to a lower, ultimately lets down the whole of what the plant had raised; in so doing, however, giving back to the universe, in the form of heat and motion, the equivalent of the light and heat which the plant had taken from it."

Thus, as Tyndall later wrote: "As experimental contributors, Rumford, Davy, Faraday and Joule stand prominently forward; as theoretic writers (placing them alphabetically) we have Clausius, Helmholtz, Kirchoff, Mayer, Rankine, Thomson," and he distinguishes sharply between the two classes, as the world of science always must, without denying to either credit for that practical genius which makes the work of the one party useful or for that genius of foresight and insight which often leads the other far in advance of the investigator, giving quantitative values to relations thus earlier recognized.

Thus, also, the ideas now taking expression as scientific statements of nature's laws originated in a distant age, grew into form with experience and observation and restricted experimental research, until, with the opening of the XIXth century, and with the enormous development of scientific method and of experimental systems, and with the production in marvelous exactness and perfection of every form of instrument of research, quantities came to be exactly measured and the law of persistence of energy could be stated positively and quantitatively.

When the idea of equivalence of thermal and dynamic energies and of the formation of a thermodynamic science had come to be familiar to the leaders of scientific thought, the extension of the idea to embrace all the physical forces and energies was a simple and inevitable matter. The comprehension of all physical energies within the stated law naturally and promptly, and just as inevitably, led to the suggestion of the extension of the law to the so-called vital energies and forces and to its enunciation in that general form which permitted its application by Carpenter to the vital forces and its introduction by the biologists into their department of life and work. It was in the extension of such apparently obvious deductions to the seeming limit, and without a thought of the fact having originality at the time, that the writer, in the Vice-President's address before the American Association for the Advancement of Science, at St. Louis, in 1878, made that extension in an enunciation of the principle now called by Haeckel the 'Law of Substance.'* The de-

* At that time there were two Vice-Presidents in the organization of that Association, both of whom were expected, annually, to present addresses before the whole Association at special meetings held for that purpose.

duction from all previous experience, and the inference from all experimental work to that date, seemed entirely obvious. But, so far as the writer is aware, this expression of the 'Law of Substance,' thus enunciated in August, 1878, is unanticipated. It was then stated as follows:*

"The facts revealed by the researches of Rumford, Davy and Joule have been grouped and systematically united by Rankine, Thomson, Clausius and other scarcely less eminent men and the science of thermodynamics, which has been thus created, has been applied and put to the proof by Hirn and other distinguished engineers of our own time. Finally, it has now become evident that this last is but another branch of the universal science of energetics, which governs all effective forces in all departments of science. The man is still to be found who is to combine all the facts of this latest and most comprehensive of all sciences into one consistent and symmetrical whole and to illustrate its applications in all methods of exhibition of kinetic energy.

* * * *

"The grand principle which we are just beginning to indistinctly perceive, and to recognize as underlying every branch of knowledge and as forming the foundation of all positive science, seems, when stated, to be simply an axiom. The Scriptural declaration that the world shall endure until its Maker shall decree its destruction by Omnipotence is but a statement of a principle which is more and more generally admitted as a scientific truth, viz.:

"The two products of creation, matter and force, and the fruit of their union, energy, are indestructible.

"The grand underlying basis of all science is found in the principle:

"All that has been created by infinite power—matter and its attribute, force, and all energy—is indestructible by finite power and shall continue to exist, so long as the hand of the Creator is withheld from its destruction."

"This 'Law of Substance,' as Haeckel proposes to call it, the writer then stated, has "been admitted almost from the time of Lavoisier, so far as it affects matter; it has been admitted as applicable to physical energies since the doctrine of the correlation of forces and of the persistence of energy became accepted by men of science and we are gradually progressing toward the establishment of a *Law of Persistence of all Existence*, whether of matter, of force and energy, or of organic vitality, and perhaps even to its extension until it includes intellectual and soul-life."

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*Proc. A. A. A. S., Twenty-seventh Meeting, at St. Louis, Mo., 1878; Sec. A, Mathematics, Physics and Chemistry; Address of the Vice-President, p. 43. *Vide* also Thurston's 'Manual of the Steam Engine,' Vol. I., 1st Ed., 1891, Chap. III., p. 241.

"The truths of science are thus coming into evident accord with those doctrines of religious belief which are common to all creeds. We are, however, as far as ever from the determination of the question whether those higher forms of force and energy have quantivalent relations and intertransformability; although a belief that mind and matter have a certain identity, and that in matter can be discerned 'the promise and potency of all terrestrial life,' has been avowed, explicitly or implicitly, by more than one great thinker when wandering into the realms of speculation."

In this, Tyndall long anticipated our contemporary writers.* Lavoisier showed to the satisfaction of the scientific men of his time that matter is indestructible, whatever the apparent result of chemical action. Faraday, and probably many among his predecessors, recognized that the forces are indestructible, and that great investigator wrote:

"To admit that force may be destructible, or can altogether disappear, would be to admit that matter could be uncreated; for we know matter only by its forces."†

Liebig fully recognized the distinction between the proper use, of the term, force and energy, and usually called the latter 'power,' as when he says:

"Man by food not only maintains the perfect structure of the body, but he daily inlays a store of power and heat, derived in the first instance from the sun. This power and heat, latent for a time, reappears and again becomes active when the living structures are resolved by the vital processes into their original elements."‡

Carpenter clearly saw these distinctions and recognized the nature of energy, as distinguished from force, when, in his discussion of the action of the vital forces, he asserted:

"What the germ really supplies is not the force but the directive agency; thus rather resembling the control exercised by the superintendent builder, who is charged with working out the designs of the architect, than the bodily force of the workmen who labor under his guidance in the construction of the fabric."§

Carpenter says explicitly:

"Hence we seem justified in affirming that the correlation between heat and the organizing forces of plants is not less intimate than that

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* See his 'Heat Considered as a Mode of Motion,' N. Y., D. Appleton & Co., 1864, for an admirable statement of this point and for his splendid championage of Mayer.

† 'The Conservation of Force.'

‡ 'The Connection and Equivalence of Force.'

§ 'The Correlation of Vital and Physical Forces.'

which exists between heat and motion." He includes both animal and vegetable vitality in his generalization.

"The life of man, or of any of the higher animals, essentially consists in the manifestation of forces of various kinds, of which the organism is the instrument."

All organic life involves the direction of nature's forces and their utilization by direction of the energies; but this striking and important distinction is observed, as Carpenter first definitely asserted: The animal employs energy derived by the disintegration of vegetable growth to its will-directed, and to its internal automatic, work; while the vegetable directs the energy of the sun's rays and of chemical action to the building up of new organic matter into its life-forms. A cycle thus transfers and transforms energy radiated to the earth from the sun, building up the vegetable, sacrificing the structure in the building of the animal organism, breaking down the animal structure again, and setting free the circling energy to continue its progress along other paths into other organic matter, or elsewhere, as directing agencies may compel.

Thus, in all nature and in all manifestations of natural law and of motion, general experience has satisfied us that matter is persistent, that it is endowed with inalienable properties which include the so-called physical forces, similarly persistent in their character and methods of action and their intensities, and that energy, a property of matter in motion, is also persistent, but not also permanently affecting any given mass; its total quantity is invariable, but it may be distributed indefinitely, transferred in any manner and transformed to any extent, irrespective of other than quantitative measures of matter affected. Matter not only permanently retains its characteristic forces, but, reciprocally, the forces permanently require and maintain matter as their residence. No exception to this constancy of union of matter and forces is yet known, and the only question now remaining to be fully answered is: How far may such relations be traced into the more intangible realms of nature and life and consciousness.

Herbert Spencer has stated the fundamental idea of science in this field most concisely, accurately and clearly. He says in 'First Principles': "We cannot go on merging derivative truths in these wider truths from which they are derived without reaching at last a wider truth which can be merged in no other or derived from no other. And whoever contemplates the relation in which it stands to the truths of science in general will see that this truth, transcending demonstration, is the *Persistence of Force.*" Indeed, Faraday had already, years before, asserted this law to be the highest that our faculties can appreciate in physical science. In fact, as we may perhaps still more strongly put it: The Law of the Persistence of Substance, including its every attribute,

must necessarily underlie every permanent existence and the universe itself.

The number of world-riddles, as Haeckel says, is diminishing rapidly, and our scientific knowledge has come to be so far-reaching that if we cannot resolve every minor problem of the universe, we have at least gone far toward the solution of the mightiest among the larger questions. One 'comprehensive question,' as he calls it, remains: What is the foundation of the 'Law of Substance,' the law of the persistence of matter and its attribute, force?

"What is the real character of this mighty world-wonder that the realistic scientist calls Nature or the Universe, that the idealist philosopher calls Substance or the Cosmos, what the pious believer calls God?"

"We must admit that we know as little of its essence, as did the ancients or the philosophers of the later centuries, up to our own. The mystery deepens as we probe it; there remains beneath all and behind all an apparently 'unknowable,' to-day, as in all earlier times." Haeckel throws no new light upon this eternal sphinx-life. He claims that the eternity of matter, with its inalienable eternity of unchanging attributes, its eternally persistent motion and energy, means eternal life of the universe, with never-ending renewal of such movements as we are now conscious of and in this probably all men of science are ready to agree with him. But he goes on to assert that the necessary conclusion is the destruction of 'the three central dogmas of the dualistic philosophy—the personality of God, the immortality of the soul and the freedom of the will.' He finds few philosophers willing to go with him to the end of his logic and thinks that 'consecutive thought is a rare phenomenon in nature.' The majority of philosophers are desirous of clinging to the old beliefs on the one hand, while taking hold of the monism of the newer time on the other, seeking to ride both the differently moving steeds and usually ending by dropping from the younger at the limit of their powers of holding on.

This has undoubtedly been true in the past and will probably remain true in the future and as long as man retains his apparently eternal and immortal convictions relating to a higher power; but, admitting Haeckel's accusation and going with him to the ultimate of his deduced facts and law, it seems extremely probable that, arrived at its end, they will all be found much in the position of Haeckel himself, confronting the deduction of Clausius and Lord Kelvin, and will still ask the unanswerable question:

What lies beyond? Who or What inaugurated this eternity? What or Who originated matter? What or Who marked the limits of the universe? If limitless: Who and What filled it with matter and motion and life?

There will still within the soul of every thinking human being re-

main the conviction, apparently implanted at the origin of things, of some real 'First Cause,' of some necessary beginning of our time, space and life, and a conviction that what we call eternity affords time and the universe space for all the evolution of higher life that imperfect human nature aspires to. It will be admitted that, as Goethe says:

'By eternal laws of Iron Rules,
Must all fulfil the cycle of their destiny.'

All can see that

'The times are changed, old systems fall,
And new life o'er their ruins dawns;'

yet, as in all past times, new interpretations and adjustments of the beliefs and the creeds of the fathers will be found to reconcile fundamental principles in religion and in morals with the older inspirations and the newer readings of the Book of Nature, and we may unquestionably hope that, in the future as in the past, the newer readings will tend toward evolution of higher thought, nobler life, more perfectly ideal and spiritual philosophy. We may all go with Haeckel and the greatest interpreters of the laws of Nature, and yet may find it possible to look beyond the limits of things seen into 'The Unseen Universe' with no loss of the spiritual.

Haeckel is one of the few, even among scientific men, who accept the necessary, or apparently necessary, conclusions coming of his logic to the very extremity and, in this case, he finds them carrying him to the deduction that there can be no immortal life of the individual soul. Whether this conclusion must follow or not, he is more far-reaching in his deductions relating to physical phenomena, as consequences of the 'Law of Substance,' than any among his predecessors; for he accepts the conclusion that there cannot be a dead eternity and that there must be some return from that swing of the pendulum which, with Sir William Thomson (now Lord Kelvin), left a cold and still universe to eternal death. This he finds absurd and admits the probability that the backward swing will come, during the eternities, through the occasional collision of suns, suns and planets, planet with planet, of binary systems and meteoric masses and star-dust, such as have been actually, not infrequently, seen during our own historic period, by the astronomer at his telescope, and by his ancestor, the astrologer, and even occasionally by the unobservant people of all times. Such a collision is sufficient in its development of thermal energy to reduce the colliding bodies into vapor and to disperse it throughout space in nebula and meteoric matter, and to renew the cycle.

As Haeckel says: The law of the persistence of force proves, also, that the idea of a 'perpetuum mobile' is just as applicable to, and as significant for, the cosmos as a whole, as it is impossible for the isolated action of any part of it. Hence the theory of '*entropy*' is likewise unten-

able. It is not the fact that the 'end of the world' is to come as supposed in the theories of entropy and with the degradation of energy to a uniform and unchanging lifelessness. Sooner or later—and time is nothing, 'a thousand years are but as a day'—sooner or later, the collection of masses will return mass-energy to the form of molecular and atomic energy, now here, now there, throughout the universe, and the round of eternities will be unceasing. "The eternal drama begins afresh—the rotating mass, the condensation of its parts, the formation of new meteorites, their combination into larger bodies, and so on."*

* 'The Riddle of Existence'; pp. 239-248.

THE HEIGHT AND WEIGHT OF THE CUBAN TEACHERS,

WITH COMMENTS ON THEIR PHYSICAL STATUS COMPARED WITH THE AMERICANS.

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WHEN the Cuban teachers were in Cambridge last summer, it was commonly observed that they seemed to be smaller in size and stature than our own American teachers and students. This impression was undoubtedly favored by the peculiar manner in which some of the Cubans wore their clothing. Many of the men had their coats cut in at the waist, and wore them tightly buttoned about the waist and chest, while the trousers were large and full, especially at the knee. This gave the bodies of the men a lean and slender appearance. Most of the women went without their hats when going to and from the recitation halls, and, although many wore high-heeled shoes, the diminutive stature was very apparent.

In order to determine the facts as to the physical status of the Cuban teachers, about a thousand (973) of them were measured and weighed at the Hemenway Gymnasium at Harvard University during the first week in August, 1900. As this work was undertaken in connection with the regular work of the Harvard Summer School of Physical Training, the time that could be given to the measurements was necessarily limited, and the height and weight were the only physical observations taken and recorded. In order to facilitate the work, each teacher was given a card to fill out, upon which were blank spaces for his number, date of measurement, name, date of birth, and his own and his parents' nationality. The cards distributed to the women were pink in color; those given to the men were green. These cards were brought to the gymnasium by the persons who desired to be measured, and the height and weight, taken in inches and pounds, were entered upon the cards, which were then left to be tabulated. Contrary to the usual custom with American students, the height and weight of the Cubans were taken with the clothing and shoes on. Three-quarters of an inch were allowed for the height of the heel of the shoe, and six per cent. of the total weight of each woman and seven per cent. of the total weight of each man was allowed for the weight of the clothing. The subtraction of the height of the heel of the shoe and the weight of the clothing from the original height and weight as taken, make these factors in the measurement of the Cubans comparable with the

students and teachers of several of the colleges for men and women in the United States. This comparison seems to me altogether desirable, not only that we may learn something of the physical characteristics of the Cubans, in order to help them in their efforts to attain a national independence, but in order that we may learn something of our own strength and weakness, and be able to govern ourselves accordingly.

The ages of the American students measured, which we present for comparison, ranged from 16 to 30, while the ages of the Cuban teachers ranged from 16 to 60. As the growth in stature is usually completed about the twenty-second year, the number beyond this age who were measured would have little influence in raising the average height. The weight, however, may increase up to the fiftieth or sixtieth year, and if any considerable number of persons beyond the age of 30 or 40 are included in this observation, the average weight would be considerably increased. In the factor of weight, therefore, the Americans and Cubans were hardly comparable, because there were so many of the Cubans who were older than the Americans, and consequently might be expected to weigh more. The effect of this increased weight due to age shows itself in a peculiar way, as will be observed by reference to Chart 2.

After the cards were collected from the Cubans they were tabulated according to the percentile grade method advocated by Francis Galton. By this method the medium weight and height which 50 per cent. surpassed and 50 per cent. failed to reach, were determined, also the values which smaller and larger per cents. exceeded or fell short of.

In referring to Table No. 1 it will be observed that there were 973 Cuban teachers measured. Four hundred and seventy-nine of these were men and 494 women. The youngest man was 16 years of age, and the oldest 64, while the youngest woman was 13, and the oldest 59. The medium age, *i. e.*, the age which 50 per cent. surpassed and 50 per cent. fell short of, was 27 years for the men and 24 years for the women. Ten per cent. of the men were more than 44 years of age, and 10 per cent. of the women were 38 years and over. The table of American college students with whom the Cuban teachers were compared was made up from the measurements of about 3,000 men and 2,000 women, taken more than fifteen years ago. It is only fair to state that the average height and weight in several of these institutions for both sexes has increased somewhat since then. Of this number comprising the American table, the youngest man was 16, and the oldest 45, while the youngest woman was 15, and the oldest 40. The medium age of the male student was 20 years, and the medium age of the female student was 18.8 years. Ninety-five per cent. of the American male students were under 26 years of age, which was the age surpassed by

TABLE I.

No.	Above.	95	90	80	70	60	50	40	30	20	10	5	Above.	
	Below.	5	10	20	30	40	50	60	70	80	90	95	Below.	
	Minimum												Maximum	
Nationality.						*Age.*								*Number*
Cuban Men.....	16	18	19	21	23	24	27	30	34	39	44	49	64	479
Cuban Women.....	13	17	18	19	20	22	24	26	28	33	38	46	59	494
American Men.....	16	17	18	18	19	19	20	20	21	22	24	46	45	3000+
American Women...	15	16	16.5	17	18	18.2	18.8	19	20	21	23	25	40	2000+
						Height.								
American Men.....	54.7	63.9	64.6	65.7	66.5	67	67.7	68.2	69	69.8	70.9	71.7	75.6	3000+
Cuban Men.....	55.9	60.2	61	62.2	63.1	63.8	64.3	65.1	65.7	66.5	67.7	68.5	75.6	479
American Women...	53.2	59.1	59.8	60.6	61.4	61.8	62.6	63.1	63.8	64.6	65.5	66.2	71.3	2000+
Cuban Women.....	54.7	57.2	57.9	59.1	59.5	59.9	60.3	61	61.5	62.2	63.4	64.2	68.9	494
						Weight.								
American Men.....	72.8	110.3	114.7	121.4	125.8	130.2	134.5	138.9	143.3	147.8	156.6	165.3	229.3	3000+
Cuban Men.....	85	94	99	104	108	112	114	119	123	129	138	150	202	479
American Women...	77.2	92.6	97	102	108	111	114.6	119	122	129	137	145	218	2000+
Cuban Women.....	74	80	85	91	95	99	102	106	110	117	128	138	220	494

over 50 per cent. of the Cuban male teachers. Although the Cuban female teachers were younger than the Cuban male teachers, 60 per cent. of the former had attained an age which was only surpassed by 5 per cent. of the American female students. Almost all the extra attainments in stature and in weight that may be attributable to age are, therefore, in possession of the Cubans.

In comparing the distribution of height and weight among the two nationalities (see Table No. 1 and Charts Nos. 1 and 2), some interesting and suggestive facts are brought to our attention. Among the American male students measured, the shortest was 54.7 inches and the tallest was 75.6 inches. Among the Cuban male teachers the shortest was 55.9 inches and the tallest was 75.6. Although there is but little difference in the extremes represented by the two nationalities, the difference in the stature attained by the greatest number in the two groups is very striking. The medium height of the American male student is 67.7 inches, while only 10 per cent. of the Cuban male teachers attain this stature. The medium height of the Cuban male teachers was found to be 64.3 inches, but this height is surpassed by over 90 per cent. of the American male students.

Upon referring to the figures giving the height of the women, it will be observed that the American female students have a greater range of extremes, as would naturally follow from their larger numbers, the tallest American being 71.3 inches and the shortest 53.2, while the tallest Cuban female teacher was 68.9 inches and the shortest 54.7 inches. The medium height of the American female student is 62.6 inches, and the medium height of the Cuban female teacher is 60.3 inches. Over 80 per cent. of the American female students surpass the stature attained by 50 per cent. of the Cuban female teachers, or only 20 per cent. of the latter attain a stature of 62.2 inches, which is surpassed by 50 per cent. of the former.

The distribution of weights (see Table No. 1) in the two groups is equally striking and suggestive. The heaviest American male student in the group weighed 229.3 pounds, and the lightest weighed 72.8 pounds. The heaviest Cuban male teacher weighed 202 pounds, and the lightest 85 pounds. The medium weight of the American male student was 134.5 pounds, and the medium weight of the Cuban male teacher was 114 pounds. More than 90 per cent. of the American male students surpass in weight the 114 pounds attained by only 50 per cent. of the Cuban males, and only 5 per cent. of the latter exceeded 150 pounds.

The heaviest American female student in the group weighed 218 pounds, and the lightest 77.2 pounds. The heaviest Cuban female teacher weighed 220 pounds and the lightest 74 pounds, which surpasses the American females in the two extremes. The medium weight of the American female student was 114.6 pounds, and the medium

weight of the Cuban female teacher was 102 pounds. Eighty per cent. of the American female students surpass the medium weight of the Cuban female teachers, but on the other hand, 10 per cent. of the Cuban women surpass 128 pounds in weight, which is exceeded by only 20 per cent. of the American women students.

Many other interesting comparisons may readily be made. Upon referring to Table 2, some of the differences in the several percentile grades of the two sexes and nationalities readily become apparent.

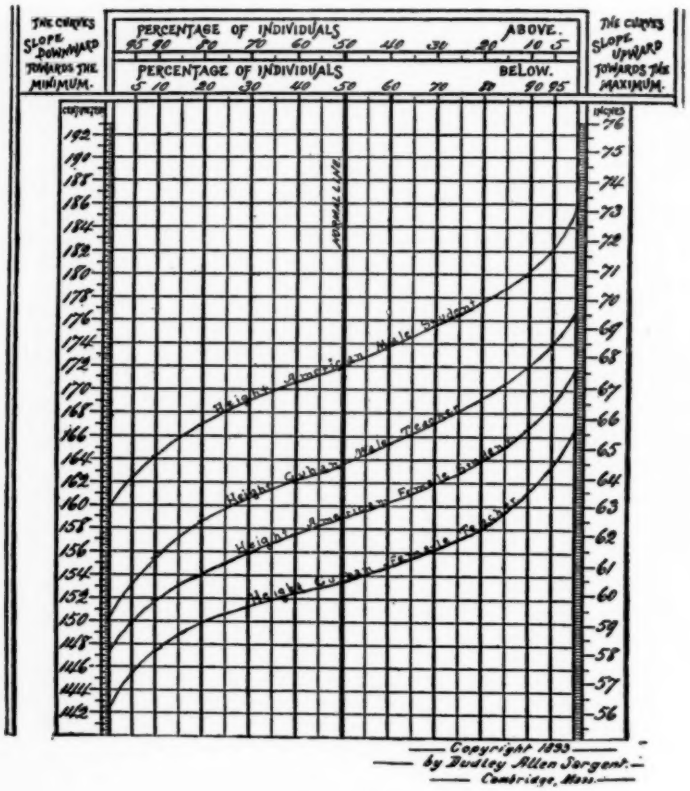
THE CURVES SLOPE DOWNWARD TOWARDS THE MINIMUM.
PERCENTAGE OF INDIVIDUALS ABOVE.
95 90 80 70 60 50 40 30 20 10 5
PERCENTAGE OF INDIVIDUALS BELOW.
5 10 20 30 40 50 60 70 80 90 95
THE CURVES SLOPE UPWARD TOWARDS THE MAXIMUM.
CENTIMETRES
INCHES
AVERAGE LINE
Height American Male Students
Height Cuban Male Teachers
Height American Female Students
Height Cuban Female Teachers
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CHART 1.

The medium Cuban man is 12 pounds heavier than the medium Cuban woman, but the smaller Cuban men are 13 or 14 pounds heavier than the smaller Cuban women, while the larger Cuban men are only 2 and 6 pounds heavier than the larger Cuban women. This would seem to indicate that the Cuban women tend to take on flesh as they grow older much more readily than the Cuban men, or that through some selective agency the larger and stronger type of Cuban man is not well represented among the teaching force. In all probability, the

stronger and heavier men would have entered the army or engaged in some more vigorous occupation than teaching school.

Among the many things that interested the Cubans in our people was the freedom of our women and the opportunities they enjoyed for growth and development, both mentally and physically. But what shall we say to the fact that the medium American woman is 19.9 pounds lighter than the medium American man, and that the difference increases in the man's favor all through the different percentile grades.

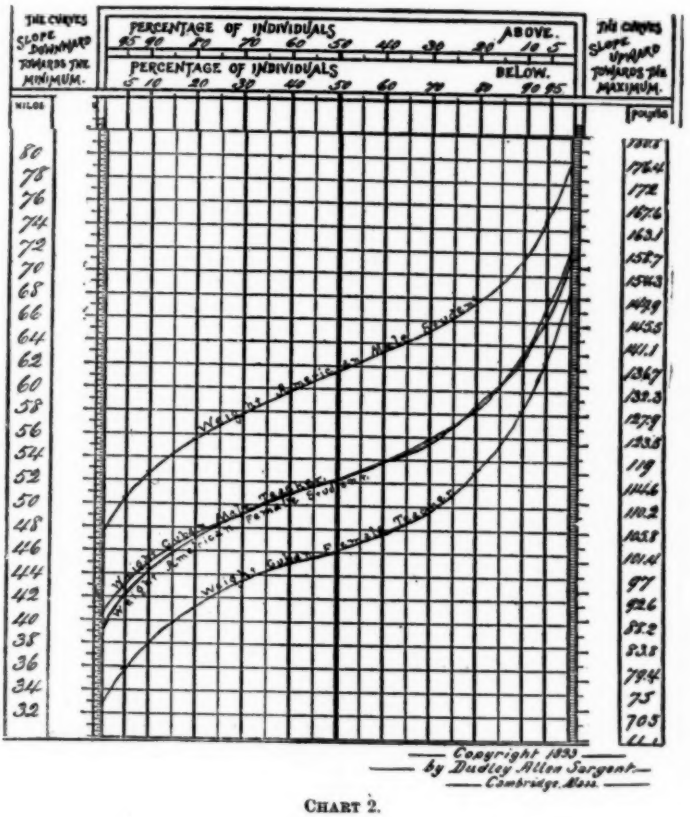
THE CURVES SLOPE DOWNWARD TOWARDS THE MINIMUM.
PERCENTAGE OF INDIVIDUALS ABOVE.
95 90 80 70 60 50 40 30 20 10 5
PERCENTAGE OF INDIVIDUALS BELOW.
5 10 20 30 40 50 60 70 80 90 95
THE CURVES SLOPE UPWARD TOWARDS THE MAXIMUM.
KILOS
pounds
80 78 76 74 72 70 68 66 64 62 60 58 56 54 52 50 48 46 44 42 40 38 36 34 32
176.4 172 167.6 163.1 158.7 154.3 149.9 145.5 141.1 136.7 132.3 127.9 123.5 119 114.6 110.2 105.8 101.4 97 92.6 88.2 83.8 79.4 75 70.5
Weights Cuban Male Teachers.
Weights American Female Students.
Weights Cuban Female Teachers.
Weights American Male Students.
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CHART 2.

If our American women have better opportunities for growth and development than the Cuban women, why do they not compare more favorably with the American men, in weight and height, than the Cuban women do with the Cuban men? Is it due to the inferiority of the American woman, or the superiority of the American man? Has the heavier and more buxom type of woman been selected, and left her leaner and lighter sister to wed the arts and sciences? Have the admirable opportunities for physical training and athletics, af-

TABLE II.

	Above.	95	90	80	70	60	50	40	30	20	10	5	Above.
	Below.	5	10	20	30	40	50	60	70	80	90	95	Below.
	Minimum												Maximum
						Difference in Weight.							
Cuban Men and Cuban Women	11	14	14	13	13	13	12	13	13	12	6	2	—18
American Men and American Women	—4.4	17.7	17.7	19.4	17.8	19.2	19.9	19.9	21.3	18 8	19.6	20.3	11.3
American Men and Cuban Men	—12.2	16.3	15.7	17.4	17.8	18.2	20.5	19.9	20.3	18.8	18.6	15.3	27.3
American Women and Cuban Women	3.2	12.6	12	11	13	12	12.6	13	12	12	5	—3	—2
						Difference in Height.							
Cuban Men and Cuban Women	1.2	3	3.1	3.1	3.6	3.9	4	4.1	4.2	4.3	4.3	4.3	6.7
American Men and American Women	1.5	4.8	4.8	5.1	5.1	5.2	5.1	5.1	6.2	5.2	5.3	5.5	4.3
American Men and Cuban Men	—1.2	3.7	3.6	3.5	3.4	3.2	3.4	3.1	3.3	3.3	3.2	3.2	0
American Women and Cuban Women	—1.5	1.9	1.9	1.5	1.9	1.9	2.3	2.1	2.3	2.4	2.1	2	2.4

forded our male students, begun to show the expected results by a general increase of weight and stature, that has not yet been attained by our college women? Can it be true that our American women are beginning to show the material cost of attempting to build a highly organized brain and maintain their special physiological function at the same time? Although in primitive races the two sexes are almost always more nearly alike physically, perhaps the little contrast between the Cuban male and female teachers as compared with the contrast between the American male and female students, may be due to the superiority of the physique of the Cuban women in comparison with the physique of the Cuban men. This supposition is greatly strengthened by again comparing the difference in the medium weight of the Cuban male teacher with that of the American student. The latter is 20.5 pounds heavier than the former, which is even in excess of the amount which the American male exceeds the American female in weight. On the other hand, we find that the medium American female student exceeds the medium Cuban female teacher by 12.6 pounds, which is more than the average Cuban man exceeds the average Cuban woman. The weight of the Cuban man and the American woman is very nearly the same in all of the percentile grades, as will be observed in noticing the close proximity and correspondence of the curves in Chart No. 1.

The differences in height follow the same general trend as those in weight. (See Table No. 2.) There is a difference of 4 inches in the medium height of the Cuban man and the Cuban woman, while the difference between the American man and the American woman is 5.1 inches. In both nationalities there is less comparative difference between the small men and the small women and the large men and the large women, in point of height, in the various percentile grades, than there is difference in weight. The difference between the medium height of the American man and the Cuban man is 3.4 inches, while the difference between the medium height of the Cuban women and the American women is 2.3 inches. Here, again, in all the grades, the comparative differences in height were much less than the comparative differences in weight. In this respect it is interesting to note that most of the Cubans gained steadily in weight all the time they were in Cambridge, and many returned to Cuba in a better condition of health than when they came to the United States.

If we would inquire into the real cause of the diminutive stature and weight of the Cuban teachers of both sexes when compared with our student type, we must begin with the question of race. The agencies, conditions and environment that have been working for generations upon a people stamp their almost indelible effects upon them, and give them the physical characteristics which we readily

recognize in the different national types. Upon looking up the nationality of the Cuban teachers as recorded on their cards, we find that of the men 74 per cent. had Cuban fathers and mothers, 17 per cent. had Spanish fathers and Cuban mothers, while 2 per cent. descended from parentage of mixed Cuban, Spanish, Portuguese, French, German, Negro and American origin.

Among the women, 71 per cent. had Cuban fathers and Cuban mothers, 22 per cent. Spanish fathers and Cuban mothers, 3 per cent. Spanish fathers and Spanish mothers, while 4 per cent. had mixed descent of Cuban, American, French and Mexican origin. In both the men and women the descent is so largely Cuban and Spanish that the influence of the other nationalities would hardly be appreciable. We must look, then, to Spanish and Cuban ancestry and to the conditions under which they have lived to account in a large measure for the poor physique of their descendants as we see them to-day.

Looking up the physical status of the Spaniards, as shown by their height and weight, we find the height of the average Spaniard to be 65.64 inches, according to the report of the Anthropometric Committee of the British Association for the Advancement of Science, and Baxter's report of the soldiers entering the U. S. Army during the Civil War. In the latter report, the men from Italy, Spain and Portugal, in the order given, are shown to have had the lowest average stature of all the recruits that entered the service. Assuming that the Spanish soldiers were built on the same lines as the Cuban teachers, that is, weighing about 1.77 pounds to every inch in stature, it would make them average about 116.18 pounds. This is a very low standard of physical attainment, and ranks the Spanish immigrants who come to this country with the Portuguese, Hungarians, Hindoos, Bavarians, Chinese and North American Esquimaux.

Concerning the causes that have led to Spain's physical, mental and moral deterioration, it is hardly necessary to speak. When we consider that during the dark days of the Inquisition, from 1481 to 1808, more than 340,000 persons were punished for their religious convictions, and 32,000 of these were burnt alive, and that thousands who represented the nation's best blood fled from the country—what other result could have been expected? Let us turn now to the island of Cuba. Columbus described the native Cubans as 'loving, tractable and peaceable; though entirely naked, their manners were decorous and praiseworthy.' Another authority says 'the early Cubans seem to have been men of medium height, broad shoulders, brown skinned, flat-featured and straight-haired.' Into this native element has been poured an infusion of Spaniards, Creoles, Negroes, Chinese and other foreign blood, with its inevitable tendency to mix races.

From a physical point of view, the Cubans of to-day are inferior to

their Spanish forefathers. This fact is attributed principally to the enervating effect of the climate, but there are other causes. The Cubans being naturally a domestic and affectionate people seek to form marital relations at a very early age. Many a young man is a father before he is eighteen years of age, by a wife a couple of years younger. Girls are considered women at the age of thirteen or fourteen, and many of them are mothers of a considerable family before they are twenty. When we consider that the human organism is not fully developed until the age of twenty-one or twenty-two, even in a tropical climate, a large number of these premature marriages and all that they imply might easily account for the physical inferiority of the race. Another custom which I understand is practised more or less extensively among the best of Cuban families, can not but have a damaging effect upon the life and health of the child, and consequently upon the adult physique. This is the pernicious habit of bandaging infants in swaddling clothes. (See 'Cuba, Past and Present,' by Richard Davey.)

The object, in all probability, is to give the child what is termed by some persons a fine figure; but, inasmuch as every attempt of this kind tends to cramp the vital organs and eventually to stunt growth and development, it would seem to be one of the customs which the Cuban ladies might well afford to abandon if they hope to rear a vigorous people. Another custom, which, however, is not confined to Cuba, is the excessive use of tobacco. But in that country, I am informed, almost every man, woman and child appears to be addicted to the habit of smoking. (See 'Cuba, Past and Present.') Tobacco may be a solace to the aged, a force regulator for many, and even a food to some persons, through the property it possesses of lowering organic activity. But this is the very reason why it should not be used by aspiring youth who wish to attain a vigorous manhood. Excessive smoking produces disturbances in the blood, mucous membranes, stomach, heart, lungs, the sense organs and in the brain and nervous system. When indulged in freely by the young, the habit of smoking causes impairment of growth, premature development and physical prostration. This custom alone, if universally practised by one or two generations, would certainly tend to dwarf the people who become enslaved by it.

A tropical climate does not invite one to active exercise, and the Cubans as a people may well be excused for not indulging in the violent athletic games now so popular with the Northern races. But it has always seemed to me strange that they do not avail themselves of the opportunities present for swimming and bathing. I understand that there are ample bathing places, but the people of either sex seem to have a prejudice against their free use. When one recalls that the South Sea Islanders of the Pacific are among the tallest and best-formed people in the world, averaging 5 feet 9.33 inches in height,

it is natural to associate their fine physiques with their passionate fondness for swimming, which is one of the best of known exercises for giving one an all-round development.

The Cubans, as a class, have been reported by different American authors to be uncleanly, and some of the Cambridge people feared that this personal neglect might prove troublesome during the Northern sojourn of their visitors. Passing over the right of the Americans to make this criticism, who were themselves criticized by Dickens and other English travelers, not so many years ago, for this same defect, and who are not even now a water-loving people—I wish to say that bathing for cleanliness, with free use of perfumed soap, etc., is of little value from a hygienic point of view, compared to the bathing that follows a profuse perspiration produced by physical exercise. If, in connection with the use of water in the summer season, the skin is frequently exposed to the direct rays of the sun, and immediate contact with the air, it will be greatly improved in its functional power. In my personal contact with young men in the examining room, I am more and more impressed with the importance of keeping the skin in good condition, not only as a means of maintaining health and preventing disease, but of adding to one's nervous and muscular power. Since custom has decreed that the body shall be altogether covered, even in the tropics, the skin has lost much of its beauty, as well as its health-preserving qualities.

A dark complexion is the result of living for a long time in a tropical climate, and is not indicative of racial inferiority, as is too frequently assumed where the white and black races come together. The habit which many Cuban women have of plastering their faces with rice powder until they look almost ghastly, seems to us very singular, in view of the fact that so many of our own well-bred youth of both sexes spend their summer vacations at the seashore or in the mountains, earnestly endeavoring to acquire a tanned skin and a bronzed or olive-brown complexion.

Another custom which prevailed among many of the Cuban women who were in Cambridge was that of wearing narrow-toed, high-heeled shoes. The Cubans have naturally small hands and feet, and perhaps it is pardonable for a people to affect to exaggerate a little the thing upon which they pride themselves. Here, again, we see something of Spanish blood and the traditions of slavery. Those who toil for a living have large hands and feet: slaves toil for a living; therefore, slaves have large hands and feet. Those who do not have to work for a living have small hands and feet: ladies do not have to work for a living; therefore, ladies have small hands and feet. It is only necessary to carry this line of reasoning a step farther to see why the Chinese aristocrat bandages the feet of his daughter until they become so small

and crippled that she cannot walk, or the prospective Spanish aristocrat crowds her feet into pointed-toed shoes, with heel in the middle of the foot, with the same result. This inability to walk with ease and comfort was made very apparent among the Cuban teachers in their historical and geological excursions about Cambridge. Upon investigation, it was found that the Cuban women were wearing narrow, pointed-toed shoes, with high heels, numbering in sizes from two to four, and that the Cuban men were wearing the same style shoe, numbering in size from three to six. These are the sizes usually worn by our American boys and girls ranging in age from ten to fourteen. Our women wear shoes ranging in size from No. 2½ to 8, and our men shoes ranging in size from No. 6 to 10.

Of course, a smaller stature on the part of both Cuban men and women implies smaller feet, but in order that the feet, though small, should be of service, the toes and joints must be allowed freedom of movement. This they cannot obtain if the feet are crowded into small, tight-fitting, stiff-soled, high-heeled shoes.

Our American men and women, after enduring years of pedal infirmities, have at last learned the value of common-sense shoes. The interest in tennis, golf, cross-country walking and other forms of physical exercise has done much to bring about a needed reform in America in caring for the feet. It is a recognized fact that conquering armies often depend as much upon their ability to march as they do upon their ability to fight. So, in more senses than one, it is necessary for a people to get a footing in the world before they think of competing with rivals or maintaining their independence as a nation.

While we all rejoice in the efforts of the Cubans to improve the condition of their schools, and admire their interest and enthusiasm for intellectual attainments—let it be remembered that every nation that has risen to eminence in this respect has always had a strong physical foundation to build upon. My observations among the Cubans have led me to believe that they are not so far behind the Americans in point of mental ability and acumen as they are in lack of physical vigor, and some moral aim or purpose to strive for. This condition is partly due to the effects of a tropical climate, and the corrupting influence of an effete civilization like that maintained in the Island of Cuba so many years by the Spanish Government. But I have already pointed out some of the physical defects of the Cuban people that are the outcome largely of faulty habits of living—short stature, light weight, flat chests, slender waists, small hands, little, narrow feet and emaciated limbs. These are fundamental defects, and are usually associated with a relatively feeble digestion, weak heart and incapacious lungs.

The remedies I would suggest are equally fundamental. Restraint

from conjugal relations and the breeding of children until both sexes have completed their growth and development. Eating more food and drinking less coffee. Abstinence from the use of tobacco during the period of adolescence. Proper clothing for infants and children, and freedom from the restrictive and cramping influence of coverings for the trunk, limbs and feet at all times. The establishment of systematic habits of exercising and bathing from early youth to adult life, in view of attaining greater physical beauty and perfection. Arouse an ambition in young men to be strong, active and courageous, and incite them to the practise of such sports and games as tend to cultivate these qualities. Kindle among the young women an admiration for large, vigorous and manly men, in preference to little men, with effeminate airs and graces. A few years of strenuous living with these simple ideals in view will not only make the future Cubans larger and stronger than the present generation, but will go a long way towards enabling even the present Cubans to realize some of their higher ideals and nobler aspirations.

THROWING A HIGH EXPLOSIVE FROM POWDER GUNS.

By HUDSON MAXIM.

THERE is now at Sandy Hook a battery of pneumatic torpedo guns, and another at the port of San Francisco, the largest of which have a caliber of fifteen inches and are capable of throwing a maximum charge of 500 pounds of nitro-gelatin about a mile. Even to attain this range, it is necessary to fire at a very high angle. The projectile has no power whatever of penetration, being only a thin casing, about an eighth of an inch thick.

The purpose of these guns was to drop dynamite upon the deck of war vessels, or into the water to explode near them. These batteries are necessarily provided with a large plant of engines, boilers and air compressors, which, together with the long and cumbersome pneumatic guns and mountings, present unusual difficulties in their protection from the fire of an enemy, while the range is so short that a modern battleship could approach within what, for it, would be a comparatively short range, and destroy the entire outfit, without in turn being in the least exposed to the fire of the pneumatic tubes. Even should a battleship, in order to enter the Channel, be obliged to pass within range of the pneumatic guns, it would be by mere chance that one of the torpedo bombs could be dropped anywhere near it.

We will grant, however, that should these guns score a hit, with 500 pounds of nitro-gelatin, the stanchest battleship would have cause to tremble, especially should the bomb drop into the water and explode near the unprotected hull.

The pneumatic gun owes its existence to a misconception of the nature and possibilities of high explosives and of the requirements of a system for their successful projection from ordnance. Congress appropriated the money for the construction of the pneumatic batteries now in service from the same misapprehension of their utility. The 'Vesuvius,' with its pneumatic guns, was also the child of error. The shots fired by her at the fortifications of Santiago resulted in nothing more serious than the production of loud reports, which possibly frightened the enemy. Her projectiles had no power of penetration, and, therefore, were useless against fortifications.

It must be borne in mind, however, that the modern powder gun, with its small caliber and ponderous weight, throwing a heavy steel projectile, with but a small bursting charge of black powder, or with

none at all, and the unwieldy armor-clad battleship are also only the children of experiment and have not yet passed the experimental stage. These constitute one extreme of the problem, while the pneumatic torpedo gun is the other. In the belief of the writer, the large-bored cannon for throwing high explosives at high velocity, propelled by smokeless gunpowder, instead of by compressed air, is a mean between the extremes, which is destined to solve the problem; while the present form of cannon and the armor-clad warship, on the one hand, will be relegated to the rear, and the pneumatic gun, on the other hand, will fall into oblivion.

It was with a view to the solution of the problem of successfully throwing high explosives from powder guns that the writer developed the progressive smokeless powder, which has been adopted by the United States Government, and by the use of which higher velocities with lower pressures are secured than would be possible by any other means. A special form of multi-perforated powder grains, invented by the writer, for throwing aerial torpedoes from guns, makes it possible to so control the pressures, even when full charges are employed, as to warrant the use of guns having a very large caliber and comparatively thin walls. I found that several high explosives could be made sufficiently insensitive to withstand the shock of acceleration in powder guns necessary to any desired velocity.

There was, however, at that time, no means known for making a fuse which should carry a sufficient quantity of detonative material, such as fulminate of mercury or a similar compound, in order to detonate effectually the insensitive high explosive charge on reaching the target. When such a quantity of fulminate was employed, there was danger of its being exploded by the shock of the propelling charge of gunpowder, and in turn setting off the high explosive charge of the shell and bursting the gun.

I designed and patented a fuse in 1895, in which the detonator was positioned at the rear of the shell, and completely outside of the high explosive charge, with the whole strong wall of the shell base between it and the high explosive, in which position, should the fuse go off prematurely from shock in the gun, the detonator would blow out at the rear and no damage would be done, as the high explosive would be beyond its reach. When, however, the projectile with its fuse struck the target, the body of detonative compound was thrown violently forward in a guide tube and into the high explosive bursting charge, due to the retardation of the projectile.

To carry out the foregoing experiments, I built two powder mills at Maxim, near Lakewood, N. J. It was there that the Maxim-Schüpphaus smokeless powder was produced, and there I conducted a large number of experiments with a long four-inch gun, having pres-

sure gauges at different points along the whole length of the barrel, by which it was possible to ascertain not only how much pressure was exerted behind a projectile at the instant of firing, but how well the pressure was maintained behind it all along the bore. From this gun a torpedo shell, made thin and filled with Maximite and having a very heavy base portion filled with lead to act as tamping, was fired against an armor plate three and one-half inches thick and four feet square, demolishing it completely. The quantity of high explosive carried was only two pounds.

After the completion of the experiments at Maxim, N. J., and the successful testing of the Maxim-Schüpphaus powder by the United States Government, followed by its adoption, I went to England, with a view to the disposition of the foreign patent rights. On the 24th of June, 1897, I delivered a lecture before the Royal United Service Institution of Great Britain, on 'A New System of Throwing High Explosives from Ordnance.'

I explained and illustrated how a torpedo gun could be constructed which would weigh no more and cost no more than the ordinary twelve-inch seacoast rifle, but which should have a caliber twice as great, and which would stand a chamber pressure sufficiently high to throw a projectile carrying half a ton of high explosive at as great a velocity as that imparted to the usual 1,000-pound shell thrown from the 12-inch gun, and which carries only 37 pounds of black rifle powder.

I showed diagrams giving the range of destructiveness of such aerial torpedoes when striking in the water adjacent to a battleship, and claimed that such a quantity striking on board or against the armored side, under high velocity, would, without question, throw the vessel out of action.

This lecture was very widely commented upon in both the general and the scientific press, and it was stated in the House of Parliament, by one of the members who was opposing the appropriations for so many large battleships, that it would be necessary, in the event of war, and after the aerial torpedo was introduced, to keep battleships snugly in harbor and roof the harbors over to protect them.

THE GATHMANN GUN.

The Gathmann Gun Company, last year, secured an appropriation from Congress for a large torpedo gun, which was constructed by the Bethlehem Ironworks, and now lies at the Sandy Hook Proving Grounds, awaiting tests.

This gun is very like that proposed by me in the above-mentioned lecture, excepting that the caliber is not quite so large for the weight,

although the caliber, which is eighteen inches, will doubtless prove sufficient to enable the gun to give a good account of itself.

In the trials of this gun, made by the builders with a charge of Maxim-Schüpphaus smokeless powder, a projectile weighing a ton was hurled at a velocity of 1,900 feet per second with a pressure of only 19,000 pounds to the square inch. As the gun will safely stand a pressure of 25,000 pounds to the square inch, a velocity of more than 2,000 feet per second can obviously be readily obtained, as against the velocity of from 2,000 to 2,250 feet per second for the 1,000 pound shell from the 12-inch gun, with a pressure of 35,000 pounds to the square inch. We must note here that the weight of the Gathmann gun is only 59 tons, against 52 tons for the 12-inch seacoast rifle.

A bill now before Congress calls for an appropriation for the efficient testing of this weapon. The service projectile, which will be thrown from this gun in the coming test, will carry about 475 pounds of wet, compressed guncotton, or 700 pounds of Maximite. Maximite being 50 per cent. heavier than guncotton, the shell will hold 225 pounds more of that material. There are to be 24 shots at full velocity, some for range and accuracy, and others to show the effect on powerful structures erected on the land. The last and final test will be against a steel barge anchored off shore, presenting a side fully armored and supported, so as to offer even greater resistance than would be afforded by the side of the strongest battleship now afloat.

Although Mr. Gathmann is my competitor, I feel much gratified at his success in procuring from the Government the necessary appropriations for building and testing this gun, and I am of the opinion that the results of these tests will prove a source of gratification to all the taxpayers of the country, who, unless the gun proves successful, will be called upon to contribute hundreds of millions of dollars for building and arming a fleet of monster battleships, which will not be required after one shot has been fired against the steel barge which will be provided for the purpose.

The war vessel that must follow as a natural result of the success of the aerial torpedo will be an unarmored, or only partially armored, gunboat or cruiser of small dimensions, capable of traveling at very high speed. It will be a sort of floating gun-platform, and will cost only a fraction of what the battleship costs, while a single one of these gunboats will afford far more protection than the most powerful battleship.

MAXIMITE.

The United States Government has, during the last two years, been putting forth especial efforts to thoroughly investigate the qualities and merits of high explosives, with a view to finding the best bursting

charge for shells. A large number of explosive compounds have been submitted by various inventors and tested by the Ordnance Department of the United States Army at the Sandy Hook Proving Grounds.

Some of the explosive compounds submitted have given very satisfactory results. Perhaps half a dozen of them would serve fairly well, if nothing better could be found. The Government, however, has placed its standard of excellence very high, with the hope of finding, if possible, something better than is possessed by other countries.

The United States Government was one of the last to adopt a smokeless powder, notwithstanding the fact that it was one of the first to experiment with these new explosives. But the Departments then having the matter in charge were very conservative, taking nothing for granted, were uninfluenced by the example of other countries and were determined that nothing but the best would be good enough for Uncle Sam. The result is that this Government to-day possesses a smokeless powder superior to that adopted by any other country. The same policy has been manifested in the search for a high explosive suitable as a bursting charge for shells.

The tests through which a high explosive must pass before there is the least hope of its meeting the requirements of the Government are very severe. The inventive Yankee, having an ambition to serve the Government by producing for its use a satisfactory high explosive, has a difficult task before him. In the first place, the compound must be perfectly stable, and to determine this it is submitted to a severe heat test for a period of fifteen minutes. If it fails to stand this test it is condemned at once, and goes no further. If it passes the heat test satisfactorily, a quantity is then placed under a falling weight or hammer to test its sensitiveness or its ability to resist shock. This is determined by the height from which it is necessary for the hammer to fall in order to explode the material. If the explosive proves sufficiently insensitive to indicate that it will stand the impact or shock of penetrating armor plate, it is then tested to determine its explosive power. A forged steel armor-piercing shell is filled with the material and armed with a very powerful exploder, which is set off by electricity. The force of the explosive is shown by the number and character of the fragments. Small shells are burst for fragmentation in a steel-walled chamber; larger shells are buried in the sand and exploded, the fragments being recovered by sifting the sand.

If the number of fragments indicates a sufficiently high explosive power, an armor-piercing shell is filled with the compound and fired through a nickel steel plate, so thick as to almost stop the shell in passing through, leaving just velocity enough to carry it a few feet into a sand butt back of the plate, where it may be dug out and recovered, provided the explosive proves to be sufficiently insensitive to

stand the shock of impact, and does not explode on the instant of striking the plate. This is a very severe test—the severest of all. An explosive which will stand this impact on the plate, where the entire velocity of the projectile is overcome, while moving its length through the plate, is proved to be so insensitive that there can be no danger in its projection from ordnance at any desired velocity. That is to say, there will be no danger of the explosive going off in the gun, because the shock of acceleration in the gun is necessarily very much less than the shock of retardation when the projectile strikes the armor-plate.

Maximite has passed all of the above tests satisfactorily. When it was subjected to the heat test and no change was manifested at the

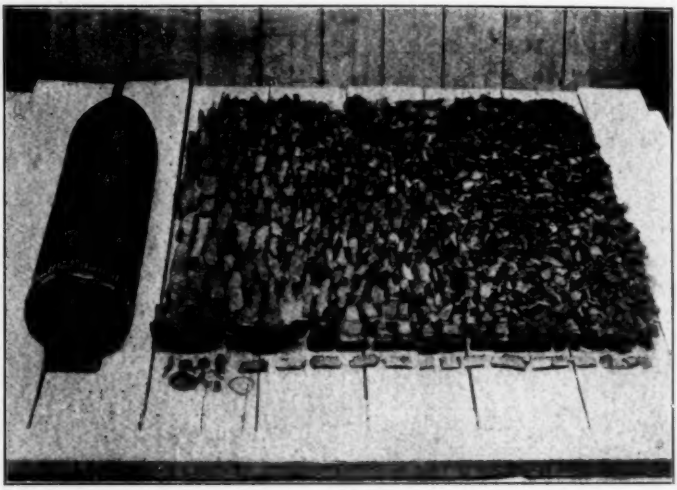


FIG. 1.

Twelve-inch forged steel armor-piercing shell, weighing 1,000 lbs., before and after exploding the Maximite. There are about 7,000 fragments shown in the photograph from which this illustration was made.

end of fifteen minutes—the required time—the material was allowed, at my request, to remain under the test for a period of two hours, and there were no signs of decomposition even then.

A 12-inch forged steel armor-piercing shell, weighing 1,000 pounds, and provided with a detonating fuse, having electrical connections for firing, was filled with Maximite. The shell was buried in the sand and exploded. So terrific was the detonation that 7,000 fragments were actually recovered and photographed.

The accompanying illustration, Fig. 1, shows the shell before exploding. On the right of the shell are 7,000 fragments which were recovered. It will be observed that the fragments do not have the

usual broken appearance, but are much distorted by the violence of the explosion.

A five-inch armor-piercing projectile was next filled with Maximite and fired through an armor plate, as above described, the projectile being afterwards recovered intact. It was found that the shock had in no way affected the explosive. The shell was then armed with a fuse and fired by electricity. The number and character of the fragments showed that the same force was developed in proportion to the weight of the shell, as in the case of the large 12-inch shell above mentioned, which was exploded in the sand. The five-inch shell is shown in Fig. 2. The fragments recovered after the explosion are shown on the right of the shell.

The next test was with projectiles filled with Maximite fired against

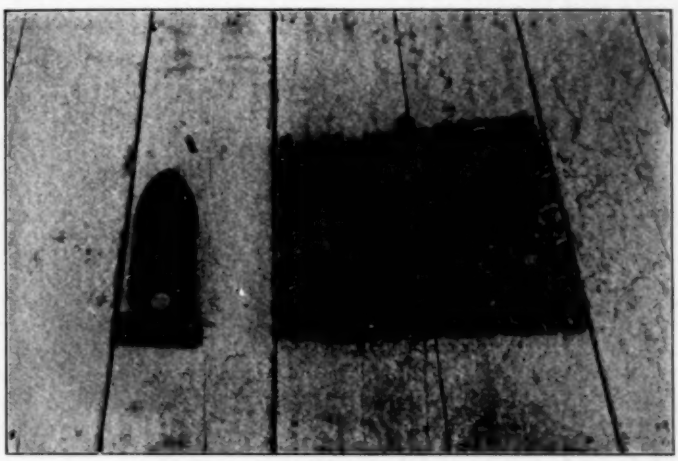


FIG. 2.

Five-inch forged steel armor-piercing projectile, weight 45 lbs., before and after exploding the Maximite. This shell, after filling with the explosive, was first fired through a four-inch nickel steel plate into a sand butt, where it was recovered intact. It was then exploded for fragmentation. There are a little over 800 pieces of the shell shown in the photograph, the average weight of the pieces being, therefore, about one ounce.

a concrete wall, with results which demonstrate that the power of the explosion was superior to that of any other high explosive ever thrown from a gun.

Projectiles loaded with Maximite were then fired through a wooden screen, after passing which they exploded, and the fragments went into the sea. The fragmentation was such that the appearance of the water was similar to that which would be produced by the simultaneous fire of a regiment of musketry. On this occasion, a result was produced hitherto unknown, and which, perhaps, illustrated the violence of the

explosive better than anything else. The projectiles, at the instant of explosion, were probably going at a velocity of about 2,000 feet per second. Pieces of the base plug of one of the projectiles were thrown back with such violence as to not only overcome the forward movement, but to throw them backward with a velocity estimated to be at least 1,000 feet per second.

This shows that a projectile filled with Maximite and exploded in a state of rest would have its fragments hurled at a velocity of about 3,000 feet per second, a much higher speed than that of a rifle ball, and that the forward-moving fragments, when a projectile is exploded in flight, will be hurled at a velocity something like 5,000 feet per second, or more than twice the speed of a rifle ball.

For the same reason that a large number of small bullets thrown at a high velocity are more effective and deadly than the large, heavy, slow-moving bullets formerly employed, a shell filled with such an

FIG. 3. FIG. 4. FIG. 5.

FIG. 3.

The fragments, natural size, of the point of a forged steel armor-piercing shell, exploded with Maximite, showing the ragged and shredded state of the metal produced by the explosive, with the hardened tip of the projectile broken off by the impact.

FIG. 4.

Side view of a fragment from the body of a 12-inch armor-piercing forged steel shell, exploded with Maximite. On the left of the fragment, which was the inner surface of the shell, is seen the flattening and stretching effect of the blow which it received from the explosion, as though it had been heated and then struck with a sledge-hammer, the force of the blow being so sudden and severe that the whole outer surface of the shell, except a small piece seen hanging to the fragment on the right was knocked off by the force of the impact.

FIG. 5.

View of opposite side of fragment seen in Fig. 4, showing where this piece was jammed upon a neighboring fragment with such force that its surface was made to flow like wax.

explosive as Maximite has an enormous advantage over explosives heretofore in use.

CURIOUS PROPERTIES OF MAXIMITE.

Maximite cannot be exploded by ignition. If a store-house filled with this material were set on fire, there would be no danger of explosion. Melted cast iron may be poured upon a mass of Maximite without the least danger of exploding it. When heated, it melts, and if the heating be continued, it will evaporate like water, without producing an explosion. Lyddite, the high explosive adopted by the British Government, is said to be simply picric acid. This substance is melted for filling the shells, which are preliminarily heated to about the fusion point of the material to prevent too rapid setting. The melting point of picric acid is 122° C. The melting point of pure Maximite is exactly one-half of that of picric acid. That is to say, it is 61° C. The low melting point of Maximite enables it to be fused over the ordinary water bath, but owing to the impossibility of exploding it by heat, the water bath is not used, for it may be melted over an open fire in the same manner that asphalt is melted in the street cauldrons, and with equal safety. It is not necessary to heat the shells beforehand when filling them with Maximite.

On the other hand, great care has to be taken in the fusion of picric acid, because, if it becomes ignited in quantity before fusion, while in granular form, it will detonate, and also if it be heated very much above the fusion point, it will detonate.

The high fusion point of picric acid renders it necessary to employ a special lining material for protecting the shells against the erosive effect of the acid, while Maximite has very much less erosive action upon metals, and owing to its low fusion point an ordinary coating of shellac or similar substance is all that is necessary to protect the shells.

It has been found from the experiments made by the Government that, although a high explosive may be so sensitive as to safely withstand the shock of acceleration in the gun, it may still be dangerous to fire, owing to the rapid rotation given to the projectile by the rifling of the gun, which is a rate of about 7,000 turns a minute. As a result, the projectile revolves upon the explosive before the latter has time fully to participate in its rotation. The great heat generated by this friction is apt to set fire to the explosive, causing a detonation.

Maximite requires so little heating for fusion that there is but slight contraction of the molten substance in reaching the point of solidification or freezing point. Maximite, furthermore, possesses the peculiar quality of expanding on solidifying, in the same way that water does on freezing. This causes it to set very firmly upon, and to

adhere tightly to, the walls of the shell, so that it is quite impossible for the charge to shift in the shell. In the event, however, of the shell rotating upon the Maximite charge, the surface of the substance exposed would simply melt, producing a fluid and perfectly frictionless bearing. In the Transvaal War many Lyddite shells exploded prematurely, either from shock in the gun or from the rotation of the shell upon the charge. Such prematures would be impossible with Maximite.

FIG. 6.

Three 3-inch shells, which were filled with Maximite and primed with 50 grains of fulminate of mercury. The points of the shells were blown off with the fuse without exploding the Maximite. The confinement and the force of the exploder were not sufficient to detonate the Maximite. This is a good illustration of the extreme insensitiveness of this material. (See small piles of unexploded Maximite below the fragments of the shells.)

When wet compressed guncotton is used as a shell charge, there is always some danger of a premature from the rotation of the shell upon the charge, especially when the percentage of water is not great.

VALUE OF HIGH EXPLOSIVES IN ARMOR-PIERCING SHELLS.

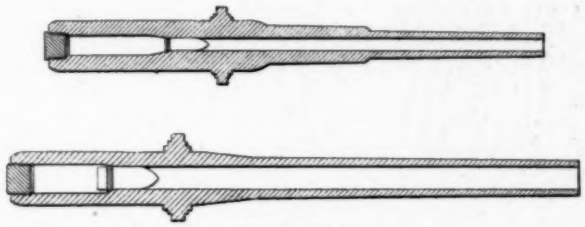
Maximite is the first high explosive, satisfactory in other respects, which could be fired through armor plate of such thickness as to render it available for armor-piercing shells.

In a recent test at the Sandy Hook Proving Grounds, a 12-inch armor-piercing forged steel shell, carrying a bursting charge of 70 pounds of Maximite, was fired through a 7-inch Harveyized nickel steel plate. This is the maximum thickness of such a plate for which

this shell is adapted; hence Maximite has shown itself capable of withstanding the shock of penetration of armor plate as thick as the armor-piercing shell itself will stand, and furthermore, in the maximum quantity which the largest shells are capable of carrying.

In the 12-inch shell for piercing still thicker armor, the charge space is considerably smaller and the length of column of explosive very much shorter, so that, although the shock upon the projectile would be greater, still the shock upon the explosive would not be any more severe than that exerted upon the Maximite in the above test.

The writer has developed a fuse which will carry 100 grains, or even more, of a fulminate of mercury compound, together with more than 2,000 grains of a picrate, through the thickest armor plate, without going off prematurely, and which will act promptly to explode the bursting charge of Maximite immediately it gets through the plate.



FIGS. 7 AND 8.

A section of the common 12-inch seacoast rifle, and a section of torpedo gun proposed by the writer in a lecture before the Royal United Service Institution of Great Britain, June, 1897.

The problem of successfully throwing high explosives from powder guns may be said to be already solved. Not only this, but the far more difficult problem has been solved, of successfully firing high explosives through armor plate to explode inside of a war vessel.

An equally important feature of the problem has also been met, and that is the safety in storage of high explosives in quantity, especially in the magazines of a battleship. The refractory character of Maximite is such that it is rendered absolutely safe under such circumstances. Furthermore, it is so insensitive that projectiles filled with it could not be exploded by other projectiles striking them and exploding among them.

In a recent test by the Government, three 3-inch shells were filled with Maximite and armed with a point fuse filled with fifty grains of fulminate of mercury, and the fuses fired by electricity. As a result, the forward ends only of the shells were blown off by the fuse, leaving the whole rear portions of the shells unbroken, and filled with unexploded Maximite. The fragments of the forward ends, which were

recovered, had the Maximite adhering to them like mortar to a brick. Another 3-inch shell was filled with picric acid, fused and fired in exactly the same manner as were the Maximite shells. The picric acid detonated with great violence, breaking the shell into small fragments. This test determined the superior insensitiveness of Maximite, and its absolute safety against even very severe shocks.

In order to effectually detonate Maximite, it must be confined in a very strong steel shell, and set off with not less than 100 grains of fulminate of mercury, reinforced with not less than 1,000 grains of some form of picrate, dry guncotton or similar substance.

In the recent tests made by the British government upon the old battleship, the "Belleisle," great havoc was found to have been wrought by the Lyddite shells whenever they penetrate through the ship's side at unprotected points, but all such shells which struck upon the armor plate exploded on impact, and did no damage. Had Maximite shells been used in this test, they would have passed through the armor plate and exploded inside the vessel.

Maximite is an entirely new chemical compound. Nothing like it, to my knowledge, has ever before been produced. Its production is based upon an entirely novel theory of detonation, which, together with the formula for the material itself, is kept a Government secret.

PYRAMID LAKE, NEVADA.

By HAROLD W. FAIRBANKS, Ph.D.
BERKELEY, CAL.

NOT much more than fifty years ago the Great Basin region, lying between the Rocky Mountains and the Sierra Nevadas, was almost unknown. Previous to 1840, a few daring men had penetrated west of the Rocky Mountains. The route to Oregon had been traversed, and one party had crossed the southern portion of the Great Basin, but the main portion was unexplored.

The maps made of the country lying west of the Rocky Mountains previous to the explorations of Fremont are most interesting, as showing the strange conceptions which men had formed of the geographic features of the region. The great Sierra Nevada range of California is entirely absent, and a number of rivers are marked as rising in the Rocky Mountains and flowing west into the Pacific.

One of these maps was used by Fremont, who first made known the real character of the region, and the journal of his wanderings in this desert waste is most interesting reading. Enabled as we are now to cross the deserts in a few hours in comfortable cars, with good maps at hand, and plenty to eat and drink, it is hard to place ourselves in the position of the early explorers of a vast and unknown region, where each day the problem of food and water has to be solved anew.

We owe much to Fremont for his daring explorations in the arid regions of the West. It was during his first expedition that he discovered Pyramid Lake, the subject of this sketch, but in trying to extricate himself and his party from the deserts, they nearly perished upon the snowy summits of the Sierra Nevada Mountains.

In the year 1843 Fremont conducted an exploring expedition to Oregon. As winter approached he turned southward from The Dalles, expecting to return to Salt Lake by way of Nevada. But upon getting into the deserts and fearing that he would not be able to cross them, he turned westward and, in the very heart of winter, attempted to cross the Sierras into California. This plan was based upon a misconception of the geography; for his map showed him no Sierra Nevada, but instead a great river called the Buenaventura, which was supposed to rise in the Rocky Mountains and flow westward into San Francisco Bay. Day after day as his party became more wearied, and food for the animals became scarcer, he watched for this river, thinking that every stream which they came to must be the one sought, but found invariably that

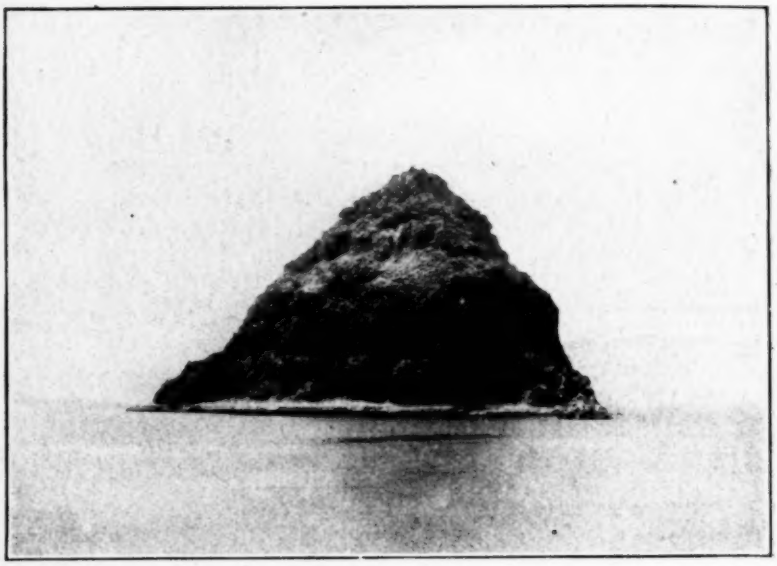


FIG. 1. PYRAMID ISLAND, PYRAMID LAKE.

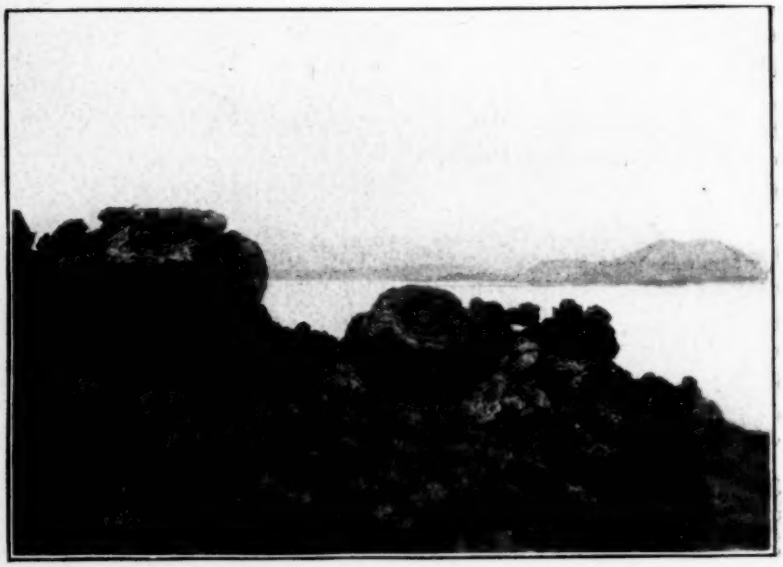


FIG. 2. TUFA DEPOSITS BY PYRAMID LAKE, SHOWING CONCENTRIC STRUCTURE.

the streams flowed in the wrong direction and emptied into lakes without outlets or into the desert sands.

As the party traveled southward into Nevada, they came upon one of the largest and most interesting of the lakes of the Great Basin. Fremont says in his journal: "Beyond, a defile between the mountains descended rapidly about 2,000 feet; and filling all the lower space was a sheet of green water some twenty miles broad. It broke upon our eyes like the ocean. The waves were curling in the breeze and their green color showed it to be a body of deep water. For a long time we sat enjoying the view. It was like a gem in the mountains which from our position seemed to enclose it almost entirely." Thus runs the narrative of the first white man who ever saw this great body of water. Of its source and general relations he knew nothing, but he hoped that it had an outlet and that the stream would lead him westward to California.

Traveling southward along the eastern shore of the lake, the party came in sight of a great rock rising from it, and camped upon the shore opposite. Fremont says: "It rose according to our estimate 600 feet above the water, and from the point we viewed it, presented a pretty exact outline of the great pyramid of Cheops. This striking feature suggested a name for the lake and I called it Pyramid Lake."

The lake thus discovered and named has had an interesting geological history, and is surrounded by many remarkable scenic features. It occupies the deepest portion of the basin of a much greater lake which once covered much of northwestern Nevada. This extinct lake has been named Lahonton, after an early French explorer.

It must be understood that the Great Basin, as its name signifies, is an extensive region with no outlet to the ocean. It is made up of innumerable faulted crust blocks, the elevated ones giving rise to the north and south ranges of mountains and the depressed ones to the desert basins lying between. Each local basin or valley has its own watershed limited by the mountains which surround it, but if for any cause the water supply from these mountains is in excess of the evaporation in the valley, a lake results, and if the supply is sufficient the lake will overflow its own basin and spread into the adjoining basins, rising to a height at which the water lost by evaporation exactly balances the inflow.

In this manner it was that the great Lake Lahonton spread over the valleys of northwestern Nevada during the glacial period. The Walker, Carson and Truckee rivers, with many smaller ones, all heading in the glacier-covered Sierras, were supplied with a great amount of water during the heavier precipitation of that period. In addition, the heat was not so great and consequently evaporation was less.

The ancient boundaries of this lake have been traced and carefully studied, and we know that during its high-water stage it was second, in size, only to Lake Bonneville, another great lake of the same period

which occupied the basin of Great Salt Lake. The total length of Lake Lahonton from north to south was not far from 250 miles, with a width from east to west of 180 miles. Its area was more than 8,000 square miles. It was an exceedingly irregular lake, however, for it was broken up by mountain ranges into many long and narrow arms, with deep bays and long peninsulas. At the time of its greatest expansion it still had no outlet, although one arm reached far westward into Honey Lake valley, California, and another one extended into southern Oregon.

As time passed on and precipitation decreased, the supplying streams became smaller and the lake began to shrink. The basins which had been connected at high water again were separated and so there at last resulted the conditions of the present day. Many of the lakes are still

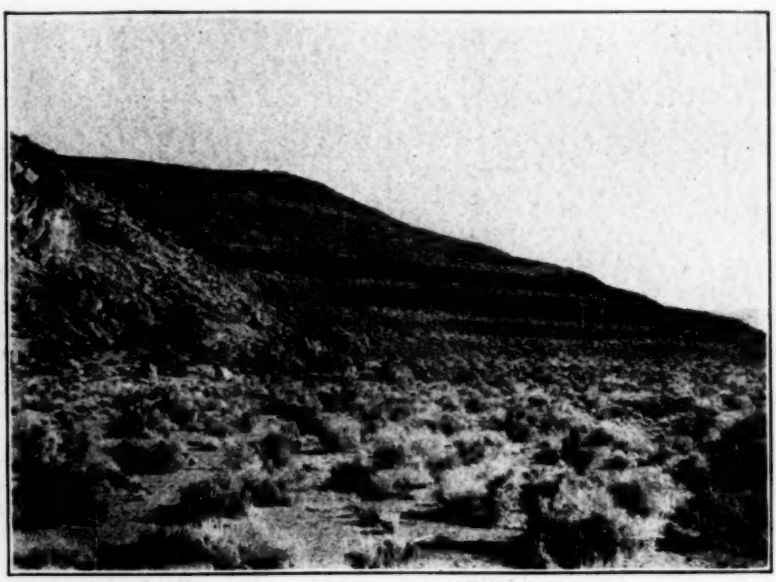


FIG. 3. TERRACES OF LAKE LAHONTON, NORTH OF PYRAMID LAKE.

shrinking, and it is difficult to tell how much of the ancient lake will eventually remain. Walker Lake, Carson Lake, Humboldt, Honey and Pyramid lakes are the remnants of the once far-reaching Lake Lahonton. The great valleys which the lake left bare are now among the most arid portions of Nevada. Notable among these is the Black Rock desert, where for many miles, and in some directions as far as the eye can reach, the barren clay floor of the old lake stretches away.

As the waters of Lake Lahonton receded they did so by stages and at every stopping-place left a well marked beach. These old beach terraces are among the most striking features of this region. One may

travel for days over the desert with the old wave-cut benches circling the mountains far above him.

Pyramid Lake occupies the deepest of the basins of Lake Lahonton. It has a depth now of about 360 feet, but the waters of the ancient lake rose 500 feet higher, making its greatest depth at the time of maximum expansion nearly 1,000 feet. Pyramid Lake has a length of thirty miles and a maximum width of ten miles. It is fed by the Truckee River, which has its source in Lake Tahoe in the high Sierras. The lake is, of course, alkaline, as are all the lakes of the Great Basin, but the water is not as strongly impregnated as some of them. It is well supplied with large trout, as well as several other kinds of fish. The water is unfit for people to drink, although it answers for stock.

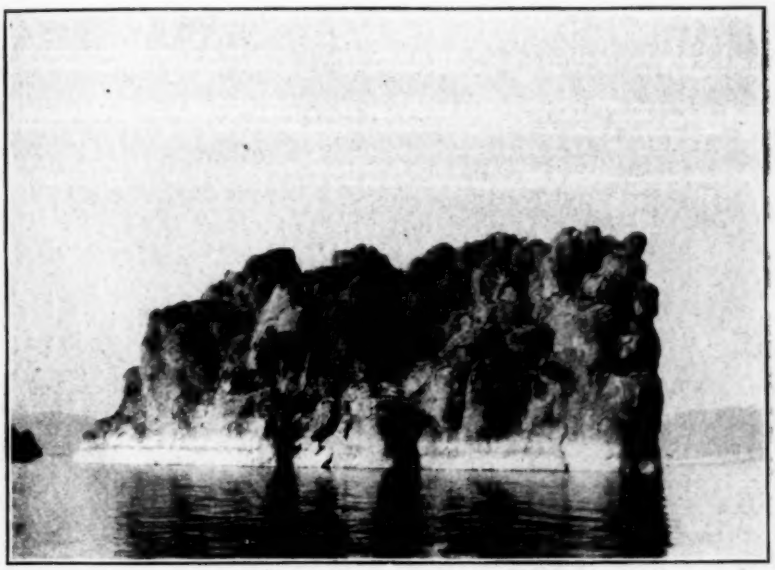


FIG. 4. TUFA DEPOSITS, NORTH END OF PYRAMID LAKE.

High mountains come down to the lake, leaving in places scarcely room for a road, and although the waters are quiet as a rule, yet they are subject to sudden and violent storms.

At many points within the basin of the former lake, Lahonton, there are strange-appearing deposits of calcareous tufa, either encrusting the rocks or rising in curious and fantastic towers and domes. The waters of the lake were richly impregnated with calcium carbonate, derived in part from the incoming streams, but more largely probably from calcareous springs. As the lake waters receded, the salts in solution became more concentrated and soon began to form chemical precipitates upon projecting rocky points. In the portion of the basin now oc-

cupied by Pyramid Lake the springs were more numerous and the water consequently more richly impregnated with lime. As a result, we find to-day in and about this lake the most interesting and remarkable tufa deposits known in all the Great Basin.

The tufa deposits are of various sorts and appearances, the differences being due to changes in the chemical properties of the water at various stages. Some of the forms are merely encrusting, and apparently structureless. Others show beautiful dendritic and interlacing figures, lapping over each other like the successive branches of some organic growth. The great deposits in Pyramid Lake have been built up in the form of towers, domes and pinnacles. The smaller ones bear a most striking resemblance to great thick mushrooms with a concentric

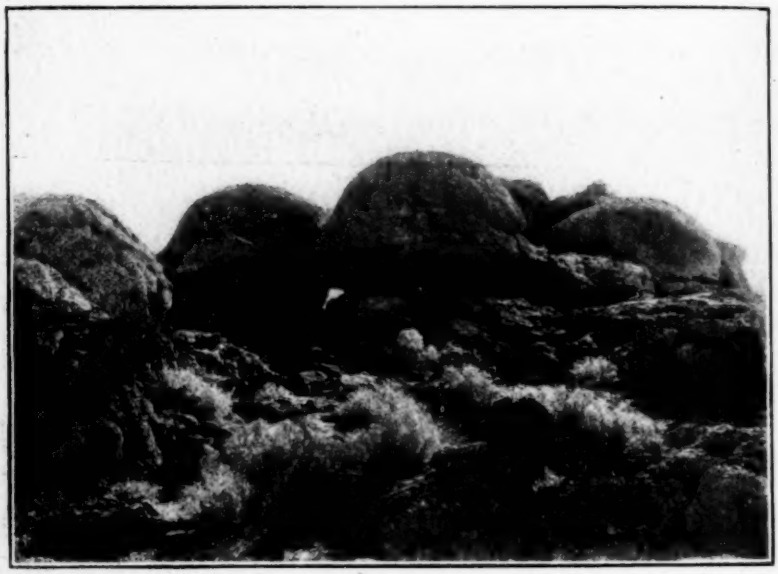


FIG. 5. TUFA DOMES, EAST SHORE OF PYRAMID LAKE. MUSHROOM-LIKE FORM.

structure. These mushroom-like growths start from some projecting point or pebble and increase in size by precipitation from the surrounding water, until, massing together, the great domes and pinnacles have been built up, rising hundreds of feet in the air.

While these deposits are still being formed in Pyramid Lake, the large ones which rise so picturesquely from the water must, of course, have been formed before Lake Lahonton had entirely disappeared, and it has been only through the continued recession of the water that the deposits have become exposed to our observation.

Following the road northward along the west side of the lake, we pass many curious forms assumed by the tufa. Here is one upon a pro-

jecting point of the shore like an old ruined castle, there by the roadside a cluster of nearly spherical domes, partly broken down and showing the concentric inner structure. But upon the far side of the lake, standing out clearly in the desert air, rises the most attractive feature of all. It is Pyramid Island, and we do not wonder at Fremont's naming it as he did.

Hiring a boat at a little ranch by the shore, we rowed across the clear and quiet waters of the lake to Pyramid and Anaho islands. The latter island is completely encrusted with the dendritic tufa, which from a distance appears like the overlapping scales upon some gigantic animal.

FIG. 6. MUSHROOM ROCK, ANAHO ISLAND.

Upon the eastern side of the islands, rising from the edge of the water there is a most picturesque deposit, known as the mushroom rock and shown in the accompanying photograph. Rising from a firm base, the deposit becomes smaller, and then at the top swells out in a spherical head.

Pyramid Island next demanded attention, and a row of a mile farther brought us close under its towering cliffs. It rises almost vertically from the water, but its sides soon become more sloping and terminate in a point nearly 300 feet high. Its shape is almost symmetrical from whichever side it is viewed. Its surface is of a very light color, and consequently it is a conspicuous landmark from all points about the lake.

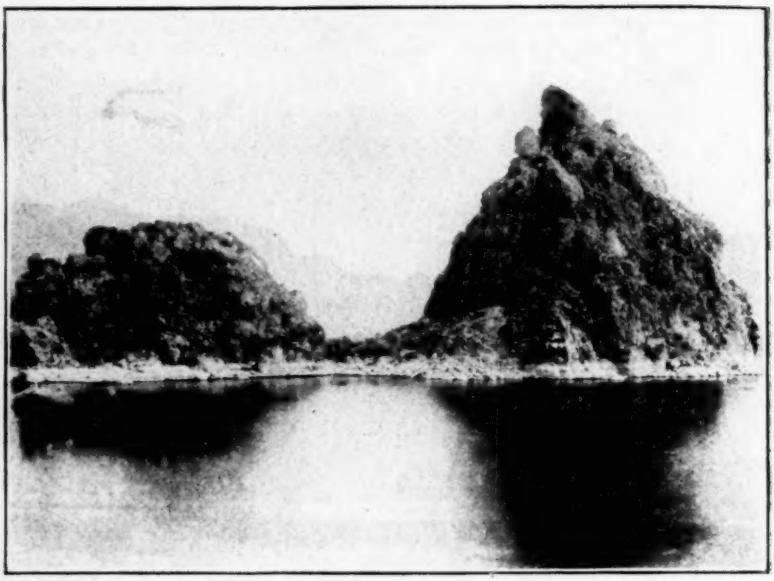


FIG. 7. ONE OF THE PINNACLES, NORTH END OF PYRAMID ISLAND.

FIG. 8. TUFA CRAGS, NORTH END OF PYRAMID LAKE.

It is but a short distance from the island to the eastern shore, where Fremont camped and made the sketch which accompanies his narrative. This is a favorite camping spot for the Indians while engaged in fishing. Upon a projecting point near here there is a large cluster of very perfect tufa domes. They are among the finest about the lake. Several of them stand out from the others and exhibit finely their manner of growth. Starting from a point upon the rocks, the mushroom-like form spreads out until eight or ten feet in diameter and is then completed by a perfect hemispherical upper surface.

Long before we reached the northern end of the lake our attention was attracted by a long line of sharply pointed crags and islands, extending out more than a mile into the lake. The most of these can be reached only by water, so securing a boat from an Indian, we pulled across the three miles of water intervening.

This group of tufa domes and crags is by far the most interesting of any about the lake. Exceedingly picturesque is the effect as one rows among them, gliding over the quiet waters, from whose clear depths rise these fantastic forms. Some are low and rounded, their mammillary or botryoidal surfaces made up of an aggregation of domes. Others are more angular, rising sharply from the water's edge to a height of 300 feet. Beautiful beaches of clean sand stretch between those nearer the shore, sand marked most regularly by the waves of the lake at different stages, as it slowly recedes through the summer months. Upon a warm summer's day when the lake glistens in the sunlight, the caves in the tufa offer most inviting retreats, and the clean gently shelving beaches and comfortably tempered water are irresistible. One enjoys a bath in the mineral waters, but must be careful not to stay in them too long, for they are so strongly impregnated with alkalies that the skin is soon affected.

During the high-water stages of the lake these picturesque towers grew up beneath its surface from numerous warm springs carrying lime in solution. Springs still issue at various places, and the tufa can be observed in process of formation. It is soft and spongy, crushing under one's feet as one walks over the surface, but slightly above the summer level of the lake.

These rocks, as well as those at the southern end of the lake, are the resort of thousands of sea birds, many of which nest here. Pelicans, sea gulls, terns, geese, ducks, etc., abound. The pelican rookeries are large and particularly interesting, with the great uncouth birds swimming about in large numbers and the downy young waddling around the nests. The cavities and nooks in the tufa offer especially convenient nesting places for many of the birds. Then, too, they are seldom molested in this remote place.

Another interesting feature about the life of these rocks is the multi-

tude of spiders. One cannot climb over them without being covered with the webs and distributing hundreds of the little insects. But few bushes grow upon the tufa, for the rainfall here is very slight, and they are clearly revealed in all their nakedness.

Exceedingly barren are the shores of this great lake, except at two points where springs furnish water for irrigation. The Truckee River has rich bottoms along its lower course, occupied by Indians who seem to be fairly well civilized.

Although the lake is so isolated, its scenery is remarkable in the extreme, and it deserves to be better known. More plainly than is usually the case, the history of the ancient lake which occupied these valleys is recorded on the slopes of the surrounding mountains and in the strange tufa deposits which rise out of the waters of its modern representative, Pyramid Lake. Rising and falling with the different seasons, the lake seems to have slight hold upon life. If the Truckee River should be entirely diverted to Winnemucca Lake, the waters of Pyramid Lake would undoubtedly shrink to insignificant proportions. The same effect would be brought about if the aridity of the Great Basin region should increase, and the precipitation upon the Sierra Nevada become less than at present.

Let us hope that, in the swinging of the pendulum from arid to more moist conditions and back again, the lakes of the Great Basin are not doomed to extinction, but that they may again increase in size, repeating the conditions of the past.

THE GEOLOGIST AWHEEL.

By Professor WILLIAM H. HOBBS,
UNIVERSITY OF WISCONSIN.

IN no country of the world does the government distribute to its people with so lavish a hand as in our own the published results of scientific investigation. One example among many that might be given is furnished by the reports of the United States Geological Survey, which for abundance of material, for scientific value and for beauty of illustration are not approached by the geological publications of any European state. Of the many who see the beautifully colored geological maps which accompany these magnificent reports, or the only less elaborate and expensive maps prepared by certain of the individual States, doubtless few have the faintest notion of the studies on which they are based.

No comprehensive study can be made of the geology of any region until some sort of geographical map of the region makes it possible to represent the exposed rock masses in approximately their true positions relative to one another. If the geology be other than of the very simplest character—and this will generally be true of mountainous regions—it is not only necessary to fix the geographical positions of rock masses, but their elevations as well. In other words, the map must not only be a plan, but special elevations must be represented, known as geological sections. The most satisfactory representation—and this will be essential for all difficult areas—will be one which shows not only special elevations, but the topographic relief of every point in the area. A proper preparation for detailed geological work in a difficult area involves, therefore, the making of a relief or topographic map based on correct triangulation, and of a scale and an accuracy of delineation of relief forms commensurate with the complexity of the geological structure. For large areas of the eastern United States such maps have been prepared by the United States Government, sometimes in cooperation with the State governments, and these maps may be obtained in the form of beautifully engraved atlas sheets by any one and at merely nominal prices. On these maps are shown in black the railroads, highways, houses, etc. (the culture); in blue, the lakes, streams, swampy areas, etc. (the hydrography); and in brown, the lines of approximately equal altitude (the topography).

With such a map the field geologist can begin intelligently his geological work. This work will consist first of all in the collecting of his

data, that is, the visiting and examination of a great number of rock exposures well distributed over the area, and the careful location of each upon his topographical map, with observations indicated by special characters and colors. Where the region is thinly settled and roads are few, access will be difficult and the location of exposures doubly so, since no well determined points upon the map will generally be found near at hand from which to fix direction or to measure distance. In the comparatively thickly populated Atlantic section of the United States there will, however, be found large areas within which the highways form an elaborate network, and the location of outcrops will here be comparatively easy; a road corner, a sharp bend of a highway, a house, or other characteristic landmark being generally near enough to furnish a basis of measurement. It is for a study of such areas that the present paper is especially intended.

In the past the field geologist engaged in areal and structural work has depended either upon his own power of locomotion or upon the use of a saddle horse or a team. In the northeastern United States the numerous fences restrict his use of a horse to the highways themselves, and the difficulty of hiring suitable saddle horses has practically eliminated them from consideration. When teams are used they must very frequently be left while rock exposures are sought or examined, and the time thus lost in hitching in suitable places is very considerable. Further, a horse requires food and water, protection from flies, etc., and its hire varies from one to three dollars per day.

The advent of the bicycle has greatly facilitated the study of regions where roads are frequent, though geologists seem to be slow to appreciate its advantages. The increasing number of official government or State geologists, of university professors, and of teachers and students generally who engage in geological work may well excuse one for urging the advantages in effectiveness, in cheapness and in comfort of a properly equipped bicycle for this and similar forms of scientific work. One of the greatest of these advantages arises from the attached cyclometer, which if read and recorded at road corners and other landmarks affords one at all times either a perfect location (in case an exposure is found on the highway), or a convenient base (if an excursion must be made away from the road).

The most convenient form of cyclometer for geological work is one which can be attached to the axle of the forward wheel of the bicycle between the prongs of the fork. The slight disadvantage of being compelled to bring the wheel to a definite position before reading the cyclometer is small when compared to the danger of injuring the usual form through the falling of the wheel or from contact with objects by which the wheel is left supported. It is, moreover, frequently desirable to ship the wheel as baggage on railway trains, and it is generally better on

these occasions to remove the ordinary type of cyclometer lest it be broken or injured in handling. All this danger is avoided in the improved form of cyclometer which is attached to the center of the axle.

The equipment of the geologist will generally consist of a collecting bag with separate compartments for note book, maps, and rock specimens; a hammer, compass and aneroid barometer. In regions of low relief the aneroid is of little service and may be dispensed with, but the best method of carrying the other articles of the geologist's equipment is a question of considerable importance.

The collecting bag which is in use by government parties operating in the northern Atlantic States may be deserving of a special description, inasmuch as it is an evolution of many years. It is made of the best grade of russet leather and has four compartments. The map compartment is merely a double back within which the maps, properly protected, are slipped. The note book compartment is sewed on the front of the bag and shaped to the book. In the main central compartment of the bag the specimens are stowed and in a wide but shallow pocket sewed to its back near the top are kept the black and colored pencils, the eraser, horn protractor, and small ebonite triangle, for use in the making of notes and in plotting the observations upon the map. The cover of the bag is a flap fastened by a strap to a buckle on the front and near the bottom of the note book compartment. When carried on the person the bag is supported by a wide strap passing through loops on the sides and bottom so as to carry the weight from below. On the wheel the bag is supported by a light framework of strong galvanized iron wire, which by means of three leather straps is securely fastened to the handle bar and the head of the machine. The bag fits loosely into the frame, even when filled with specimens, and it is kept in place on rough roads by being attached by two straps furnished with snaps to the handle bar of the bicycle. The bag can thus be almost instantly attached to the wheel or removed from it and slung by the carrying strap over the shoulder.

The topographic map sheets which are used for the base in the geological work are cut in half and each of these halves is again divided so as to be mounted on the inside of two cloth covered and hinged boards, as is the lining to a book cover. This method of mounting secures a smooth surface and a firm support to the map, gives a large area always at hand so that geological relationships may be easily appreciated, and furnishes moreover the best possible protection to the records of the work. Hardly less important is the protection which these stiff boards afford to the leather back of the bag when they are slipped within its map compartment, and also to the body of the geologist when the bag is loaded with heavy specimens and carried from the shoulder.

The best form of compass is doubtless the four-inch aluminum dial compass with clinometer attachment, which is manufactured by Gurley

for the United States Geological Survey, but cheaper and simpler instruments can be made to serve almost as well. This instrument is best carried in a leather box worn upon the belt. The aneroid, if used, is carried in a leather case slung from the shoulder and passed under the belt so as to be shaken as little as possible. The hammer is most conveniently carried upon the person by slipping the handle through the belt, a 'pick' or prospector's form being specially secure in this position because of its long head. When riding the hammer is slipped under a strap on the side of the carrying frame of the rock bag.

Where observations must be frequently taken, as in detailed areal mapping, considerable time may be lost in finding a suitable support against which to rest the wheel. Bicycle manufacturers should be able to devise a light and simple support which can be carried with the wheel and quickly adjusted. In a region adapted to bicycle work, such as much of the Piedmont Plateau and the Coastal Plain of the eastern United States, as well as large areas in Europe, it is believed that a bicycle outfit such as is here described makes it possible to reduce greatly the expense and to divide by at least one-half the time necessary for mapping over that required if older methods of locomotion and transportation are employed. The inertia of long-established practise is, however, considerable, and geologists have been somewhat slow to adopt the newer methods. The small expense of such an equipment and the accessibility of the beautiful government maps make it possible for private and essentially amateur geologists, with the advantages of only a brief geological training and a moderate amount of experience, to collect valuable data within the area surrounding their homes, especially if these chance to be in a thickly settled part of the country.

THE FORMATION OF HABITS IN THE TURTLE.*

By ROBERT MEARNS YERKES,
HARVARD UNIVERSITY.

HABITS are determinants in human life. It is true that we are free, within limits, to form them; it is also true that, once formed, they mold our lives. In the life of the brute habit plays an even more important rôle than it does in man. The ability to survive, for example, frequently depends upon the readiness with which new feeding habits can be formed. So, too, in case of dangers habitually avoided, those individuals which form habits most quickly have the best chances of life. But it is unnecessary to emphasize the importance of habit to all living beings, for it is obvious. We have now to ask, What precisely is a habit?

A habit proves in analysis to be nothing more or less than a tendency toward a certain action or line of conduct—a tendency due to structural and functional modifications of the organism which have resulted from repetition of the action itself; for nothing can be done by the animal mechanism without resultant changes in its organization. These changes it is which influence all subsequent activities and constitute the physical basis of habit. Repetition of an act apparently leads to the formation of a track for the controlling nervous impulse—a line of least resistance, so to speak—along which the current therefore *tends* to pass. A duck when thrown into the water does not have to stop to think what to do to get out, how to move this leg and then that; it instinctively, we say, meets the situation with that combination of movements called swimming. But the duck swims almost, if not quite, as well the first time it is put into the water as it ever does. There is little profiting by experience. This simply means that the structural basis of the swimming habit is present at birth, and does not have to be formed by repetition of the action thereafter. The habit is, in other words, inherited. For man swimming is not an instinctive act; he has to learn every detail of the complex muscular process by trial; he has to establish by repetition of the

* This article is based upon an experimental study of the associative processes of turtles made at the Marine Biological Laboratory, Woods Holl, Mass., during the summer of 1899, under the direction of Dr. E. L. Thorndike. My thanks are due Dr. Thorndike and Prof. C. O. Whitman, the director of the laboratory, for their kindness.

activity the basis of the habit. Finally, however, the man will be able to meet the situation—water, a distant shore, and a desire to be on the shore—as the duck does—that is, habitually.

Since habits make an animal what it is in great part, the study of their formation, of the manner and rapidity of their growth, and of their permanence must be of practical as well as of scientific importance. We are rapidly realizing, as the increasing interest in animal psychology clearly indicates, that the mental life of all animal types must be understood before we can attain to a satisfactory science of psychology or give a history of the evolution of mind. To watch the progress of a habit's growth is exceedingly interesting, whether the subject be a man or one of the lower animals. Ordinarily the chief difficulties in the way of such a study are the great length of time and the constancy of observation necessary. But these obstacles may readily be avoided by making observations under artificial or experimental conditions—that is, by adapting conditions to the needs of the experiment, instead of trying to adapt one's self to natural conditions. The account which follows presents, as an example of this kind of work, observations on habit formation in the common 'speckled turtle' *(Chelopus guttatus)*. It has been my aim to give a brief account of the way in which a particular turtle profited by experience.

The work was undertaken to determine to what extent and with what rapidity turtles can learn; to measure as accurately as might be their intelligence. Reptiles are usually considered sluggish and unintelligent creatures, and there can be no question about the general truth of this opinion. Turtles certainly appear to be very stupid—so much so, indeed, that one would not expect much in the way of intelligent actions. Just how stupid, or better perhaps, just how intelligent they are, we shall be better able to judge after studying the habits of the animals more carefully, and collecting more evidence like the following:

The finding of the way through a labyrinth to a nest was chosen as the habit to be studied. The motives employed to get the subject to try to find its way to the nest were: first, the desire to hide in some dark, secluded place; secondly, the impulse to escape from confinement; and lastly, the desire to get to a place of comfort. Dr. Thorndike,* in studying the associative processes of cats and dogs (of which a brief account appeared in the POPULAR SCIENCE MONTHLY for August, 1899), used hunger as the chief motive for escape. This is unsatisfactory in the case of turtles, because they frequently do not eat well in confinement, and at best their feeding or

*'Animal Intelligence, an Experimental Study.'

desire for food is very irregular and hard to control as a motive in experimental work.

The method of experimentation was simple. A box three feet long, two feet wide and ten inches deep was divided into four portions by partitions, also ten inches deep, arranged as shown in Fig. 1. In each partition was a hole four inches long and two inches deep, just large enough to permit the turtle to pass through easily. The box is shown in ground plan by Fig. 1.

A is the space in which the animal was placed to start, the starting-point being marked by a dot (.). The corner marked nest contained a mass of damp grass and was darkened. When everything was ready for an experiment the animal was placed in *A* at the dot and allowed to wander about until it found the nest by passing through the openings marked 1, 2 and 3.

On July 20 the animal, a speckled turtle about four inches long which was found in Woods Holl, Mass., was placed in *A* for

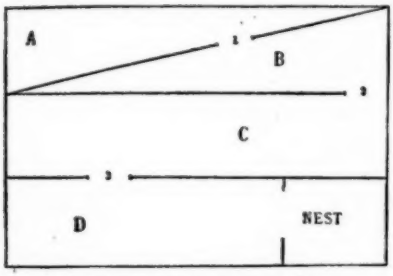


FIG. 1. PLAN OF LABYRINTH NO. 1.

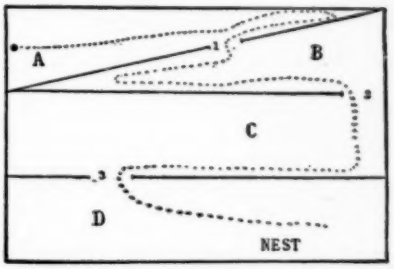


FIG. 2. COURSE FOR FOURTH TRIP.

the first time. After wandering about almost constantly for thirty-five minutes, it chanced to find the nest, into which it immediately crawled, there remaining until taken out for another experiment two hours later. The observations were made from one to two hours apart, in order to avoid fatiguing the animal, and also to leave it some inducement for seeking the nest, for if it were taken out each time as soon as it got back to the comfortable corner, the game would soon lose interest. The second time the nest was reached in fifteen minutes, with much less wandering. The time for the third trip was five minutes, and for the fourth, three minutes thirty seconds. During the first three trials the courses taken were so tortuous that it seemed foolish to try to record them. There was aimless wandering from point to point within each space, and from space to space. After the third trip the routes became much more direct, and accurate records of them were obtained. Fig. 2 gives the course taken in the fourth experiment. It is fairly direct, but shows that the animal lost its way in *A* and again in *B;* having passed through 2, it took the shortest path to the nest.

A record of the route in connection with the time of the trip is necessary as an index of the effect of experience, because if the animal takes a direct course, with no wrong turns, but makes several halts, the time may indicate no profiting by the former acts, whereas the route will at once show that there has been improvement. Thus one record supplements the other.

These experiments were made six or eight times a day until fifty trials had been given. The tenth trip was made in three minutes five seconds, with two mistakes in turning. The time of the twentieth journey was but forty-five seconds, and that of the thirtieth, forty seconds. In the latter experiment a direct course was taken; this was also true in the case of the fiftieth trip, which was made in thirty-five seconds. Fig. 3 represents graphically the times of the first twenty experiments of this series. The vertical

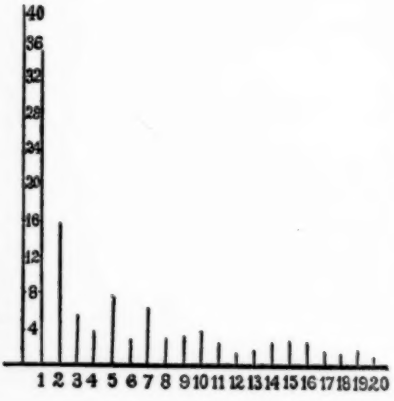


FIG. 3. TIMES OF EXPERIMENTS FROM ONE TO TWENTY.

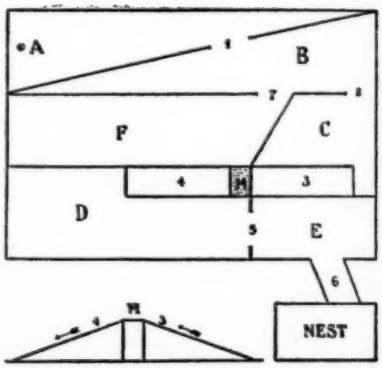


FIG. 4. PLAN OF LABYRINTH NO. 2.

column of figures at the left, 1 to 40, indicates minutes; the horizontal line of figures, 1 to 20, gives the number of trials.

That the turtle profited by experience, and that very rapidly, is evident from the figures. The average time for the first ten trips, from one to ten, was eight minutes fifty-four and a half seconds; the average time of the ten trips between thirty and forty was one minute three seconds. What at first took minutes, after a few trials required only as many seconds. There was remarkably little aimless wandering, crawling up the sides of the box and sulking in the corners after the third experiment. In fact, the animal soon began to behave as if it had the goal in mind and was intent on making directly for it. It learned with surprising quickness to make the proper turns and to take the shortest path. Three or four times I noticed it turn in the wrong direction, crawl into a corner and, as it seemed, become confused, for it then re-

turned to the starting-point, as if to get its bearings, and started out afresh. In every case the second attempt resulted in a direct and unusually quick journey to the nest. Very frequently halts just in front of the holes were noticed. It looked as if the animal were meditating upon the course to be taken. Had one seen a man in a similar situation he would unhesitatingly have said that the person was trying to decide which way to go. There can be little doubt, however, that the mental attitude of the turtle was extremely simple compared with a man's under similar conditions. There are those who would claim that even the turtle was thinking about its environmental conditions, but it seems far more probable that it stopped in order the better to get those sensory data by which it was enabled to follow its former course. Smell and sight furnish the most important elements in the associative processes of lower animals. This interpretation of the action is sup-

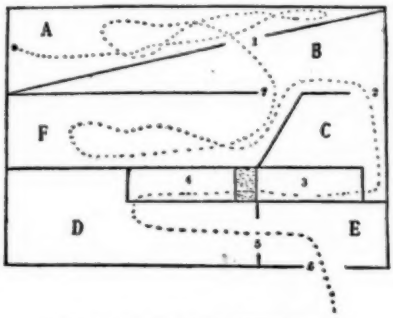


FIG. 5. COURSE FOR FIFTH TRIP.

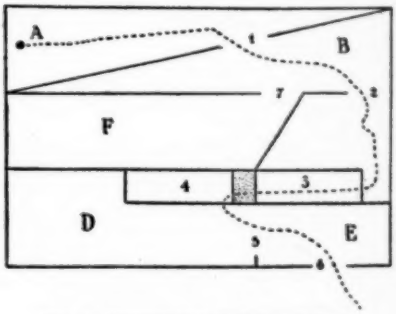


FIG. 6. COURSE FOR THIRTIETH TRIP.

ported by the fact that it occurred most frequently after the course had been gone over a few times.

A more complex and novel labyrinth was now substituted. Its new features were a blind alley (see *F*, Fig. 4) and three inclined planes (3, 4 and 6 of Fig. 4). A plan of the labyrinth is shown in Fig. 4. At the left of the nest a side view of the inclines 3 and 4 is shown. Each was one foot long, and the middle point *(M)* was four inches from the floor.

Labyrinth No. 2 was used in the same way as No. 1, the turtle being placed in *A* and permitted to seek the nest, which was this time a box filled with moist sand. The inclines at first baffled the little fellow, and it was an hour and thirty-one minutes before he reached the nest. *A* and *B* seemed to offer no difficulties, but the new features—the blind alley and the inclines—were puzzles. By the fifth trial, however, these had become somewhat familiar. The route taken in this experiment has been produced in Fig. 5.

The time of this trip was sixteen minutes. The times of some of the other trials were as follows:

10th trip	4	minutes.	
15th "	6	"	
20th "	4	"	5 seconds.
25th "	3	"	
30th "	3	"	20 seconds.
35th "	2	"	45 "
40th "	4	"	20 "
45th "	7	"	
50th "	4	"	10 seconds.

The route for the thirtieth trip was, as Fig. 6 indicates, almost direct.

The times of these experiments are generally longer than those of the first series because the inclines consumed considerable time.

During the formation of the habit of crawling up incline 3 and sliding down incline 4 a very interesting modification of the action occurred, namely, the shortening of the path to the sand-box by crawling over the edge of incline 4. At first the animal, after climbing up 3, would slide all the way to the bottom of 4 and would then turn toward the nest. Soon, however, it began making the turn toward the nest before reaching the bottom, thus throwing itself over the edge of 4. The turn was made earlier and earlier on 4, until finally it got to crawling over as soon as it reached the top of 3, or *M*. It always turned itself over the edge carefully, and landed, after a fall of four inches, usually on its head or back. By this process the path was shortened eight or ten inches. This action is a splendid illustration of the way in which an advantageous habit may grow by accretion, as it were, until it seems as if it must have been the result of reasoning. Some would, no doubt, hold that in this case the turtle chose the direct path because of inferences from judgments. Although this *may* be true, there is surely a sufficient explanation of the habit, as we have come to know it, in the profiting by chance experience. No one would say that the nest was at first found by inferences. It was reached because of the animal's impulse to move about, to seek escape or hiding. Had the turtle stopped to judge and draw inferences as to the way to escape, instead of persistently moving from place to place, it would probably be in the pen yet. No; the wandering impulse led by chance to the finding of satisfaction, turtle pleasure, in the nest. Because of this satisfaction, the action was impressed on the vital mechanism, so that there was a tendency (the beginning of a habit) toward repetition of it. Had the action failed to give satisfaction, the probability of its being repeated would have been

merely that of chance, and not chance plus the influence of the former pleasure-giving activity. The turtle happened to crawl over the edge of the incline, and, finding that this enabled it to get to the nest quicker, it continued the act, thus forming a habit.

Such experiments as these give clear pictures of habit formation in animals. They also furnish a means of measuring with considerable accuracy the rapidity of the process, the degree of intelligence and the permanence of associations, thus making possible a comparison of the mental abilities of different animals.

THE SCIENCE OF DISTANCES.*

By Sir GEORGE S. ROBERTSON, K. C. S. I.

WHEN the British Association for the Advancement of Science honored me with an invitation to preside over this Section, I accepted the distinction, thoughtfully and with sincere gratification. The selection as your president at Bradford, this great and interesting center of commercial energy, of a student of political movements who was also deeply interested in the science of geography, seemed to point suggestively to a particular branch of our subject as appropriate for an opening address. This consideration, and, to my thinking, the fitness of the occasion, led me to believe that the British Empire itself was a very proper subject for such reflections as could be compressed within the limits of an inaugural Presidential Address. Many of my predecessors have eloquently and wisely dealt with various topics of admitted geographical rectitude—with geography in its more strictly scientific study, with its nature and its purview, with its recent progress, and with the all-important question of how it could be best taught methodically and how most profitably it might be studied. In dealing with the important practical application of our science to the facts of National life—Political geography—I feel that perhaps a word of explanation is necessary. Pure geography, with its placid aloofness and its far-stretching outlook, combined sometimes with a too rigid devotion to the facts and conclusions of strict geographical research, is apt to incline many scientific minds to an admirable quiet-eyed cosmopolitanism—the cosmopolitanism of the cloistered college or the lecture theater. It perhaps also at times has a tendency to create in purely academic students a feeling of half disdain or of amicable irritability against those who love the science for its political and social suggestiveness and elucidations. Thus there is a possible danger that geographers of high intellectual caliber, with enthusiasms entirely scholarly, may come to underrate Nationality and to look upon the world and mankind as the units, and upon people and confederacies and amalgamations merely as specific instances of the general type. We know that geography is often looked upon as the science of foreign countries more especially. Such mental confusion is undoubtedly less common than it was, yet it still influences, unconsciously, the minds of many people. It is well not to

* Address of the president of the Geographical Section of the British Association for the Advancement of Science, Bradford, 1900.

forget this curious fact, and to point out, as if it required emphasizing, that there is nothing foreign to geographical thought in the association of geography and patriotism, and that the home country is worthy of careful study, particularly when, as with us, our home country is not Yorkshire, nor England, nor the United Kingdom, but the whole British Empire. That is my justification and my apology for taking Political Geography and the British Empire as my subject, if justification and apology seem to any one to be necessary. To the generous hearts of our distinguished foreign visitors who honor us quite as much as they delight us by their presence, I am sure of my appeal. Every true man loves his own country the best in the world. That beautifying love of country does not require him to be ignorant of or hate other countries. The community of the civilized nations, no longer to be described as Christendom even, for Japan has been received into it, is a mighty fact in geography no less than in politics. To love mankind one must begin by loving individuals; before attaining to true cosmopolitanism one must first be patriotic.

Now, besides dealing with the topography of the globe, geography considers also the collective distribution of all animal, vegetable and mineral productions which are found upon its surface. The aspect of the science which deals with man's environment, and with those influences which mold his national character and compel his social as well as his political organization, is profoundly interesting intrinsically and of enormous practical usefulness when rightly applied. Given the minute topography of a country, a complete description of its surface features, its rivers, mountains, plains and boundaries, a full account of its vegetable and mineral resources, a knowledge of its climatic variations, we have at once disclosed to us the scene where we may study with something like clearness man's procession through the ages. Many of the secrets of human action in the past are explained by the landforms of the globe, while existing social conditions and social organizations can often thereby be intelligently examined and understood. Persistent national characteristics are often easy to explain from such considerations. For instance, the doggedness of the Dutch river-population, caused very greatly by a perpetual struggle against the sea, or the commercial carrier-instinct of the Norwegians, those northern folk born in a country which is all sea-coast of countless indentations. Having few products to barter, the Norwegians hire themselves to transport the merchandise of other peoples. We British also were obviously predestined to isolation and insularity, when perhaps in the human period the Thames ceased to be a tributary of the Rhine. Our Irish fellow-countrymen were similarly fated for all time to lead a separate, special and national life apart from our own, when at a still earlier period, geologically, the Irish channel was formed.

Such large-scale facts are not to be overlooked; there are others, however, of varying degrees of prominence. Some merely require to be interpreted thoughtfully, while others, after diligent study, may still remain dubious and matter for speculation. Geography is the true basis of historical investigation and the elucidation of contemporary movements. At the present time great social and political changes are occurring throughout the world—in Europe, Asia, Africa, and America, and in the islands of the great seas. These changes are absolutely dependent upon the physical peculiarities of the different lands acting upon generations of men during a prolonged period of time. As a consequence of certain soils, geographical characteristics and climates, we notice how harsh surroundings have disciplined some races to hardiness and strenuous industry, accompanied by keen commercial activity, which is itself both a result of increasing population and the cause of still greater overcrowding. Then we see other people at first sight more happily circumstanced. With them the struggle to live is less ferocious, their food is found with little toil. But we perceive that the outcome of generations of Nature's favoritism has been to leave them less forceful and less ingenious in the never-ending warfare of existence. By comparison they grow feeble of defense against the hungrier nations, ravenous for provender. Man forever preys upon his own kind, and an easy life in bland surroundings induces a flabbiness which is powerless against the iron training of harsh latitudes, or against the fierce energy and the virile strength produced by hereditary wrestling with unkindly ground.

The discovery of America and Vasco da Gama's voyage round the Cape originated movements and brought into play those subtle influences of foreign lands upon alien sojourners, and through them upon their distant kindred, which alter the course of history and modify national manners and perhaps national characteristics also. The colonization of territories in the temperate zone by European Governments, separated by vast ocean-spaces from their offshoots, has given origin to new and distinct nations different from the parent stock in modes of thought and in ways of life, a result due mainly, no doubt, to local physical conditions, but in part also, if only in part, to detachment, to complete and actual severance from the mother country. This brings us to that most interesting and important topic, geographically speaking, of Distance, an aspect of our science which is of the utmost concern to traders and statesmen; indeed, an eminent German geographer defines geography as the Science of Distances. To this subject of Distance I wish in particular to direct your attention, and especially to its bearings upon the British Empire.

The British Empire is equal in size to four Europes, while its population approximates four hundred millions. Although that may

seem a somewhat grandiloquent method of description, it is a fairly accurate statement of fact. Still more interesting to us is another truth —that outside of these islands we have some ten millions of white-skinned English-speaking fellow-subjects. These islands are scarcely more than one-hundredth part of the whole Empire, although we count as four-fifths of its white population; of the total number of the Queen's subjects we are, however, no more than a tenth.

British Empire is somewhat of a misnomer, just as the North American and Australian Colonies were never colonies at all in the classical sense of the word. For the colonies are not independent of the mother country. An empire again really means a number of subject peoples brought together, and at first held together, by force. India is an empire, for instance. Some new title or phrase would have to be invented to describe accurately all the possessions of the British Crown from the government of India through all possible grades of more or less direct control until we come to some colony with representative institutions, and thence to the great commonwealths with responsible legislators and responsible cabinets. Happily, however, there is no need now for any novel designation. The style British Empire has become in time of stress a rallying cry for all the Queen's subjects, and the term has become sanctified by the noble, eager devotion shown to her Majesty, both as a beloved and venerated constitutional sovereign, and as the common bond of unity between those great self-governing daughter-nations which we in the past were accustomed to speak of as 'our colonies.' Consequently British Empire has henceforward a clearly defined, a distinct, a national significance, just as Imperialism has a special and peculiar meaning to all of us. We understand by British Empire and by British Imperialism a confederacy of many lands under the rule of her Britannic Majesty. This confederacy is dominated by white peoples—Anglo-Saxons, Celts, French-Canadians and others—knit together in most instances by the ties of blood relationship, but with equal if not greater closeness by common interests, an identical civilization and a love of liberty, in addition to that dignified but enthusiastic acceptance, already referred to, of the constitutional sovereignty of the same Queen. We may hope that generous democratic expansiveness and social assimilation will also in time detain willingly within the limits of this British confederacy of white peoples those other Christians and distant kinsfolk of ours in South Africa who are at present so bitterly antagonistic.

Ruled and controlled under liberal ideals by the center of authority there are, in addition, the great subject territories whose non-Christian population are less advanced in moral and material progress. They exhibit indeed every degree of backwardness, from the barbarism of the

savagest tribesman to the intellectual but archaic civilization of ancient Asiatic nationalities.

Concerning the British Empire, and comparing it with other empires, ancient, recent or now existing, its two most remarkable features are its prodigious and long-continued growth and the persistency of its power. It cannot to all seeming grow much larger, from lack of expansive possibility. But it is unprofitable to predict. Every step which has been taken in the way of extension, particularly of late years, has been against the wishes, and in almost passionate opposition to the views of large sections of the people. Yet the process of enlargement has gone on continually, being often in actual despite of a Government, whose members find themselves powerless to prevent absorptions and concretions which they would gladly avoid. Objections to this perpetual growth of empire in territory, and to the resulting responsibility which we not altogether willingly accept, are unanswerable theoretically. The too heavy and continually increasing strain upon our military resources every one can appreciate. The limit in power of the strongest navy in the world is at least as obvious as the vital necessity that our Navy be largely and ungrudgingly strengthened. Naturally the cry of cautious, patriotic men is the same now that it has always been—'Consolidate before you step farther.' In India, owing to conscientious and strenuous opposition to every suggestion of expansion, and to the almost violent form which that opposition often took, our progress has been on the whole slow and comparatively safe. We have (I, of course, avoid all allusion to very recent policy) as a rule consolidated, strengthened ourselves, and made our ground sure before another advance. But there is a general impression that in other parts of the world we have been hastily and unfortunately acquisitive, whether we could help it or not; that the new provinces, districts and protectorates are some of them weak to fluidity; that the great and unprecedented growth of the Empire has led to a stretching and thinning of its holding links which are overstrained by the weight of unwieldy extension and far beyond the help of a protecting hand. I hope to be able to show that in some important respects this suspicion is not altogether true; that science, human ingenuity and racial energy have given us some compensations, and that it is not paradoxical nor incorrect to say that our recent enormous growth of empire has been everywhere accompanied by a remarkable shrinkage of distances—by quicker and closer intercommunication of all its parts one with another and with the heart center. In short, the British Empire, in spite of its seemingly reckless outspread, its sometimes cloudy boundaries, its almost vague and apparently meaningless growth, is at the present day more braced together, more manageable, and more vigorous as a complete organization than it was sixty years ago. The difference between its actual extent in the last year of the

century and its size at the date of the Queen's accession can be estimated by a glance at a remarkable series of maps published in the 'Statesman's Year-book for 1897,' while since 1897, and at this instant as we all know well, its mighty bulk is being still further increased.

The world as a whole has strangely contracted owing to a bewildering increase in lines of communication, to our more detailed geographical knowledge, to the formation of new harbors, the extension of railways, the increased speed and the increased number of steamships, and the greatly augmented carrying power of great sailing vessels built of steel. Then, hardly second in importance to these influences are the great land lines and the sea-cables, the postal improvements, the telephones, and perhaps we may soon add the proved commercial utility of wireless telegraphy. This universal time diminution in verbal and personal contact has brought the colonies, our dependencies, protectorates, and our dependencies of dependencies, closer to each other and all of them nearer still to us. Measured by time-distance, which is the controller of the merchant and the cabinet minister just as much as of the soldier, the world has indeed wonderfully contracted, and with this lessening the dominions of the Queen have been rapidly consolidating. Nor is this powerful influence by any means exhausted. In the near future we may anticipate equally remarkable improvements of a like kind, especially in railways, telegraph lines and deep-sea cables, and in other scientific discoveries for transmitting man's messages through water, in the air, or perhaps by the vibrations of the earth. For us particularly, railway schemes of expansion must be mainly relied upon to open up and connect distant parts of the Empire. Our true and only trustworthy road of intercommunication between the heart of the Empire and its limits must always be the sea. For general trade purposes, such as the convenience of business travelers, all continental lines and all the great projected railways will be helpful, whatever nation controls them; but our certain security is the sea, the sea which protects us, which has taught us to be an Imperial people. But if we ever forget that, there may be a calamitous awakening. We must not be persuaded to build—or at any rate to place reliance upon—land roads or railways through regions inhabited by tribes and peoples over whom we have not complete military as well as political control. Persian, Arabian, North African railway projects are happily rarely heard of now. As national enterprises they never were and never could be practicable, or otherwise than dangerous mistakes. We are a world-power solely because of our warships and because of our command of the sea. In the future also we shall remain a world-power only so long as we hold command of the sea in the fullest sense of the term, not merely by the force and efficiency of the fighting Navy, but by the excellence and the perfecting of our mercantile marine, by increasing its magnitude, carrying

power and speed, and by anxiously attending to its recruitment by English sailors. We must not attempt to overtax our resources to guard railway lines through foreign semi-civilized or savage countries by exported or local armies. A heavy land responsibility lies upon us already. Under a little more we might be easily overweighted and crushed down. We must concentrate all our surplus energies upon our sea communications. Therefore the railway lines which I spoke of as helping to consolidate the Empire in the near future are those only which are projected or are being built in the various colonies and dependencies, lines to distribute and to collect, to connect provinces, and feed harbors. The mighty Canadian Pacific Railway is unique in the Empire. It not only complies with all these requirements, but in addition it provides to Australia and the Eastern dependencies an alternative road, convenient and safe. As I said before, all railways, wherever built, will probably help us directly or indirectly in the long run, provided we are never committed to the protection of any one of them outside of our own boundaries.

And what has been said about railways applies, with obvious modifications, to telegraph lines and to maritime cables. The more general the extension of these, and the more numerous they become, the greater benefit there will be to this country in its double capacity as the greatest trader and the greatest carrier of merchandise in the world; while the actual equivalent to a diminution of time-distance in traveling is to be found in the instantaneous verbal message which can be despatched to the most distant point of the Empire. But we ought certainly to join all the shores of the Queen's dominions by sea-cables completely controlled by British authority. To rely upon connection between our own cables through telegraph systems stretching across foreign countries, however friendly, or to permit the ends of these sentient nerves of the Empire to emerge upon shores which might possibly become an enemy's country, is dangerous to the point of recklessness, that parent of disaster. As a melancholy instance of my meaning it is only necessary for us to remember the Pekin catastrophe—how we suffered from those dreadful intervals of dead silence, when we could not even communicate directly with our own naval officers at Taku, or with anyone beyond Shanghai, although we have in our possession a place of arms at Wei-hai-Wei upon the Gulf of Pechili. It is obvious that we ought to have an all-British cable for pure strategic purposes as far as Wei-hai-Wei, our permanent military outpost on the mainland.

Now to give some suggestions of the increased facilities for carrying merchandise, for conveying passengers quickly about the world, and for the sending of messages to all parts of the earth, a few, a very

few, salient facts may be quoted about ships—sailing ships and steam vessels—and about telegraphs and cables.

In 1870 there were no more than ten British sailing ships which exceeded or reached two thousand tons burden. In 1892 the yards on the Clyde alone launched forty-six steel sailing vessels which averaged two thousand tons each. In 1895 the number of large steel sailing ships being built in the United Kingdom was down to twenty-three, and, speaking generally, it is inevitable that sailing vessels must give way to ocean steamships for most kinds of cargo—cattle, coals, wool, grain, oil and everything else.

Now let us turn to the results in shortening journeys accomplished by the progress made in the construction and in the driving machinery of steamships within the last forty years, which has especially been fruitful in such improvements.

During this century the six months' voyage round the Cape to India became a forty and then a thirty days' journey by what was known as the overland route for mails and passengers through Egypt. By degrees it had become shorter still by the railway extensions on the Continent and by the unbroken steamship passage through the Suez Canal, until now the mails and hurrying travelers may reach London in twelve or fourteen days after leaving Bombay; and the great liners of the P. & O. Company can arrive in the Thames eight days later. This famous corporation, after her Majesty had been reigning nearly ten years, possessed only fourteen ships, with an aggregate of 14,600 tons. Now it owns a princely fleet of fifty-three ocean steamers, with a total capacity of 142,320 tons. Practically the voyage to India in her Majesty's reign has been diminished by one-half at least.

Also since the Queen's accession the passage between the British Isles and the Commonwealth of Australia has grown shorter, from the ninety days taken by the sailing clippers to the fifty-three days occupied by Brunel's 'Great Britain.' At the present time it lasts from thirty to thirty-five days by the Suez Canal route, while it has been finished in as little as twenty-eight days. Australia is consequently only half as far away, in time, as it was; while, if the Suez Canal were closed for any reason, we have at our disposal, in addition to the Cape route with its quick steamers, which is linked to us by the Pacific Ocean road, the splendid service of that Empire-consolidator, the Canadian Pacific Railway.

The important part played by the Suez Canal in this connection will be discussed a little later. Now I am merely indicating by a few well-known facts the diminution of distance by the improvements which have been made in the ships themselves and in their propelling machines.

Across the Atlantic the rapidity of traveling and the general aver-

age speed of all cargo steamers have increased remarkably. Very interesting statistics on this point were given to the British Association for the Advancement of Science last year, at Dover, by Sir William White, in the Presidential Address of Section G. We may say, without repeating details, that during the last half of the nineteenth century the breadth of the Atlantic has practically been diminished one-half.

In 1857 the Union Company contracted to carry mails in thirty-seven days to the Cape. Now the contract time is nineteen days. This again diminishes the distance by one-half. As an instance of the remarkable change which has been made in steamships within forty years, it may be mentioned that the first 'Norman' of the Union Company took forty-two days to reach the Cape, while the present 'Norman' has covered the journey in fourteen days twenty-one hours. I need not specify particularly the equivalent acceleration of speed upon other great steamship lines. All our sea distances have been shortened 50 to 60 per cent. in an identical way.

It is not too bold to predict that the Atlantic, from Queenstown to New York, will, before long, be steamed in less than four days. The question has now resolved itself simply into this—will it pay shipowners to burn so much coal as to ensure these rushing journeys before a cheaper substitute for coal is found? We know that a torpedo-destroyer has been driven through the water at the rate of forty-three miles an hour by the use of the turbo-motor instead of reciprocating engines. Consequently an enormous increase in the present speed of the great Atlantic liners is certain if the new system can be applied to large vessels. By such very swift steamers, and by the example they will set to all established and competing steamship companies, the journey to Canada and subsequently to all other parts of the Empire will be continually quickened, until predictions which would now sound extravagant will in a few years be simple every-day facts.

We must turn next to the subject of telegraphic communication especially as it relates to the British Empire.

The mazes of land-lines and of sea and ocean cables are too numerous and intricate to be described in detail. Also the general effect of this means of bringing distant people together, and its transcendent importance for political, strategic and trade purposes, need not be too much insisted upon in this place, so obvious must they be to everyone. Yet, great as has been its power and advantage in all of those directions in the past, it is certain that still greater development and still greater service to the world will follow in the future even from existing systems, not to speak of their certain and enormous possibilities of growth. In the celerity of the actual despatch of a message we need not ask for much improvement. Lightning speed will be probably sufficient for our go-ahead

children of the twentieth century. But where we may expect and shall undoubtedly get increased success is in multiplied facilities for sending telegrams all over the earth, and in widening their usefulness and convenience to all ranks and sections of the community. To obtain these necessary advantages there are two requisites—first a great and general cheapening of tariffs and, as a certain consequence of such reduced charges, a duplication or even a quadrupling of many of the present cables to prevent blocking; and, secondly, an indefinite extension of both lines and cables everywhere. Progress in submarine telegraphy undoubtedly means a lessening in the price of service and a firmer control by the State, as an obvious corollary to the large help to the companies already given by the general taxpayer, quite as much as it means those scientific inventions and scientific discoveries which the coming years have in store for us. At the present time the charges are far too high, ridiculously so as regards India, and the use of the great cables is, therefore, very often beyond the power of the small capitalist and the trader of the middle sort. Yet certain and early news is of supreme importance to large numbers of both classes. Its absence hampers or stops business, while its price is too severe a tax upon average profits. This fact has led to the invention of ingenious and elaborate codes. They might possibly have been devised in any case; but there is no doubt that messages by code would be certainly expanded so as to prevent all possible ambiguity, if telegraphing to distant countries were not so costly. The spreading of land-lines and sea-cables about the earth has gone on rapidly since 1870; to the extent that those already completed would seem even to be in advance of their requirement, if that requirement were to be measured by their full employment. Nevertheless it is to be wished that new companies could be formed and new lines laid down to excite competition and thereby to cheapen rates; or else that our Government should step in and regulate charges over subsidized British lines. For the power of the great telegraph corporations, by reason of their monetary resources, enables them to overcome ordinary rivalry and to treat public opinion with indifference. A general cheapening of rates has constantly been followed by increased profits, earned by the resulting augmentation of traffic, but it needs an enterprising directorate to face the necessary initial expenditure, except under pressure. Boldness and foresight in finance are naturally less prominent features in the management of the great telegraph companies than contentment with a high rate of interest on invested capital. All their energy and watchfulness are employed to crush competition rather than to extend their activities indefinitely. Moreover, money-making is their business, not Imperial statesmanship. If it were a question of the added security or the close coupling-up of the Empire (which are probably synonymous) on the one hand and a

loss of profit (however splendid the dividends might still remain) on the other, we know what would be the result of their deliberations.

Important as are the sea-cables for statesmen, for strategy and for commerce, they are or will be equally important socially to keep up intimacy and swift intercourse between families half in Britain and half in India for instance, or between friends and relations in these Islands and in the great colonies. They might be made to give the sensation almost of actual contact, of holding the hand of your friend, of speaking directly to his heart. It is this interchange of personal news and private wishes, quite as much as the profound political and commercial aspects of lightning communication with all parts of the Empire, which will bind the Empire in bonds stronger than steel, easy as affection, to hold it together with unassailable power. Consequently the health and strength of the Empire depend very greatly upon a cheapening of telegraph charges. Doubtless a time will come when all our main cables of the first importance will be in the hands of Government, when they will only touch upon British territory, and when they will be all adequately protected from an enemy. Those are truly Imperialistic and patriotic aspirations. But we must never forget the grand part in bringing together, within whispering distance, as it were, the different parts of the world, and consequently of our world-wide Empire, which has been taken in the past by such Napoleonic organizers as the late Sir John Pender. It is to him and to such men as he that we owe those splendid beginnings which by means of vital reflexes from the nerve-center of the Empire have helped to fire our white fellow-subjects all over the globe with a loftier patriotism and with new, brave and broader ideals of nationality.

It was coincident with the opening of the Suez Canal in 1869 that the liveliest interest began to be taken in sea-cables, and a master-mind perceived their commercial possibilities. Before that time the success of the constructing companies had not been great. Sir John Pender then founded the famous Eastern Telegraph Company by the amalgamation of four existing lines, which had together laid down 8,500 miles of sea-cables, besides erecting land-lines also. A year later, in 1873, from three other companies he formed the Eastern Extension Australasia and China Telegraph Company, which jointly possessed 5,200 miles of submarine lines. From that date the extension of electric communication to all parts of the earth, over wild as well as over civilized countries, and beneath the salt water, has only been equaled by their average remunerativeness. Now there are 175,000 miles of submerged cables alone, of which this country owns no less than 113,000 miles. The history of some of these cables is full of interest, and might attract the delighted attention of the lover

of picturesque romance no less than the student of commercial geography. It also supplies suggestions and many facts, both to the physical geographer and to the student of seismic phenomena. Science has taught the companies to economize time, labor and material in cable-laying operations, as well as how to improve the working instruments. Human ingenuity, business perception and organizing power have shown once more their startling possibilities when directed and controlled by cool, clear-eyed intelligence combined with general mental capacity.

It is only necessary to reaffirm, for the reasons already given, the national, the imperial, the commonwealth requirement for cheap telegraphy, and the profound necessity there is both strategically and politically for complete government control by purchase, guarantee or other equitable means over main cables which connect Great Britain with her daughter states, her Indian empire, and her dependencies. Our communications with our own folk must be independent of private companies and completely independent of all foreign nations.

All the details which I have given are illustrative of man's successful energy and of his progressive ingenuity in enslaving the great forces of the earth to diminish distance, to shorten world-journeys, and to speed world-messages. Another human achievement, the piercing by Lesseps of the Suez Isthmus, has had remarkable consequences. It had been talked of in England centuries ago. Christopher Marlowe makes Tamerlane brag:

> 'And here, not far from Alexandria,
> Whereas the Tyrrhene and the Red Sea meet,
> Being distant less than full a hundred leagues,
> I meant to cut a channel to them both
> That men might quickly sail to India.'

The illustrious French engineer solved one great problem in 1869, only to originate others which are of profound importance to commercial geography—and to the British Empire most of all. The Suez Canal has brought India and the Australasian Commonwealth wonderfully near to our shores. It has greatly diminished many time-distances, but why has it not injured our Eastern trade? Also is there any danger or menace of danger to that trade? From the very beginnings of the great commerce, the Eastern trade has enriched every nation which obtained its chief share. It has been the seed of the bitterest animosities. It alienated Dutch and English, blood relations, co-religionists, co-reformers, into implacable resentment, and bitter has the retribution been. On the other hand it brought into temporary alliance such strange bedfellows as the Turks of the sixteenth century and the Venetians. At the present day

what international jealousies and heartburnings has the same rivalry not fostered! For all the trading peoples know how vital is that traffic.

In the earliest days of commercial venturings the Eastern trade focused at Alexandria, afterwards at Constantinople and the Italian 'factory' stations of the Eastern Mediterranean. Barbarous upheavals in Central Asia interrupted the current at times, but only as temporary dams. Then came Vasco da Gama's voyage round the Cape and its sequels—the diversion of the rich merchandise of the Orient from the Italian ports and from the Eastern Mediterranean to the sea-coast cities of the Atlantic. Out of the relentless scramble of the Atlantic nations for this, the grandest of the trader's prizes, the English came out bloodily triumphant and the British have remained the dominant shippers ever since. But when the Suez Canal was trenched through, a geographical reversal followed: the merchant's chief path may be said to have left the Cape circuit and to have regained the old line, with immensely added facilities, to debouch upon the Eastern Mediterranean. Why has it not affected us more profoundly? Are not geographical canons outraged by the great steamers passing by the French and Italian ports to find distributing centers in these islands? I think that theoretically it is so, even admitting that the foreign harbors are more difficult than ours. Practically only a few industries have suffered; the volume of our trade has increased greatly and it still remains easily preeminent. One of the chief explanations I believe to be this: Geographical considerations were defeated, for the time at any rate, by the excellence of our banking system when the Suez Canal was opened. The wealth of the country, then as now, instead of being separated and divided into isolated patches, was accumulated in the hands of bankers and was readily and easily available for commercial enterprises. So the necessary steamers—huge, and of special line—were built at once by our companies and launched into the Eastern trade before their rivals could begin to stir. This country had the invaluable help of its monetary facilities. Wealthy shipping corporations, once fully organized and successful, have great power, by reason of their reserves and resources, to hustle and ride off the attacks of weaker less experienced competitors. Supposing this great change had but just occurred—our advantages, though still distinct, would have been less remarkable. And in the future international trade jealousy will be keener and the competition even more severe. We must not forget that our geographical position is no longer in our favor for steamships plying from the East, and, as in the immediate past, we must throw away no chances, but seek to make up for that admitted defect by foresight, by education, by maintaining and constantly adding to our experience, and by defending and supporting that admirable sys-

tem—our national banking system—which has carried us over seemingly insurmountable obstructions to brave trade triumphs.

The general considerations which I have named might lead to the inference that actual geographical disadvantages, in trade competition for instance, may sometimes be conquered by man's resourcefulness and energy. Within obvious limitations that is certainly true. At places, as we know, the borderland between geography and many of the natural sciences is often vague and confusedly interlaced. So perhaps also with mechanical and economic science our boundaries at certain spots overlap. Quick steamers, far-reaching telegraph lines, and the piercing of isthmuses by ship-canals may at the first glance appear outside the purview of the geographer. Yet from that particular aspect of geography which I have already spoken of as the Science of Distances we perceive how relevant they are, how worthy of study. Truly ours is a very catholic science, and we have seen how even the comparative value of national banking systems may help to explain seeming geographic inconsistencies, to reconcile facts with possibly unexpected results, and to show how the human element modifies, perhaps, the strictly logical conclusions of the geographer intent upon physical conditions alone. It is for the statesman and the philosopher to speculate upon the character and the permanency of such influences. Our success as an Empire will probably depend for its continuance upon a high level of national sagacity, watchfulness and resource, to make up for certain disadvantages, as I think, of our geographical position since the cutting of the Suez Canal; and it will also depend upon the comprehensive and intelligent study of all branches of geography, not the least important of which to my view is the Science of Distances—the science of the merchant, the statesman and the strategist.

A STUDY OF BRITISH GENIUS.

By HAVELOCK ELLIS.

II. NATIONALITY AND RACE.

IT is scarcely necessary to remark that nationality and race, when used as distinguishing marks of people who all belong to the British Islands, are not identical terms and are both vague. The races—however we may describe them*—constituting the people of Great Britain are to be found in all the main divisions of the two islands, and the fact that a man is English or Scotch or Irish tells us nothing positive as to his race. Some indication of race, however, is in many cases furnished if we know the particular district to which a man's ancestors belonged, and this indication is further strengthened if we can ascertain his physical type.

In endeavoring to ascertain the ancestral roots of these eminent men I have almost entirely discarded the evidence of birthplace; so far as possible I have sought to find where a man's four grandparents belonged; if they are known to belong to four different regions it is then necessary to insert him into four groups; when the evidence is less complete he plays a correspondingly smaller part in the classification. It very rarely happens that the four grandparents can all be positively located.

I find that 76.8 per cent. of eminent British men and women are English, 15 per cent. Scotch, 5.3 per cent. Irish and 2.9 per cent. Welsh. The proportion of English is very large, but if we take the present population as a basis of estimation it fairly corresponds to England's share; this is not so, however, as regards the other parts of the United Kingdom; Wales, and especially Ireland, have too few people of genius, while Scotland has produced decidedly more than her share.†

*For an admirable and lucid summary of the present position of this question see Ripley's 'Races of Europe', ch. xii.

† In a recent careful study ('Where We Get Our Best Men,' London, 1900,) Mr. A. H. H. Maclean has shown that of some 2,500 British persons of ability belonging to the nineteenth century 70 per cent. are English, 18 per cent. Scotch, 10 per cent. Irish, and 2 per cent. Welsh. We thus find that by taking a much lower standard of ability and confining ourselves to the most recent period, Scotland stands higher than ever, while Ireland benefits very greatly at the expense of both England and Wales. This is probably not altogether an unexpected result. It is on the whole confirmed by an analysis of British 'Men of the Time,' made by Dr. Conan Doyle ('Nineteenth Century,' Aug., 1888).

If we consider separately the eminent persons in whose ancestry two or more of the elements of British nationality (English, Welsh, Scotch and Irish) are mixed we find that the English proportion is only 51 per cent., the Scotch 16.8, while the Irish element has risen to equality with the Scotch, 16.8, and the Welsh is as high as 15.4. This would seem to indicate that the Irish and the Welsh are especially adapted for cross-breeding in the production of genius.

If we turn to the eminent persons of partly foreign blood (those of wholly foreign blood, like Disraeli, the elder Herschel and Romilly, being necessarily excluded from our study) we find that they constitute a very inconsiderable proportion of the whole. A strain of foreign blood (not going further back than the grandparents) occurs, so far as the 'Dictionary' enables us to ascertain it, only forty-six times. In twenty-four of these cases the element is French (at least half of them being Huguenot), in six German, in six Dutch. The most noteworthy fact about these elements of foreign blood is the peculiarly beneficial effect a French strain has in producing intellectual ability.

It is somewhat remarkable that the geographical distribution of eminent women by no means follows that of eminent men. Here, after England, Ireland leads, and Scotland is but little ahead of Wales. The intellectual brilliancy of Irish women is, indeed, remarkable, and has been displayed in literature as well as on the stage.

These facts serve to indicate that on the whole British ability has not been very unfairly distributed over Great Britain. We are still entitled to ask whether it is also fairly distributed among the populations of different physical type inhabiting the British Islands.

In investigating this point I have supplemented the somewhat scanty information contained in the 'Dictionary' by examination of such portraits of these eminent persons as I have been able to find in the London National Portrait Gallery, and I have confined myself almost exclusively to the color of the hair and eyes. For various reasons the data thus obtained are not altogether satisfactory; the imperfect and often vague statements of the biographers, the frequently faded tones of the pictures, sometimes badly hung, have furnished indications which are often doubtful and not seldom conflicting. An artist is a reliable observer in such matters, but he is liable to disregard the facts in order to obtain his effect, as we may see in Millais's portrait of Gladstone in the National Gallery, where the eyes are represented of quite different colors, one blue, the other brown. The evidence in some cases has been so conflicting that I have had to disregard it altogether, and in many cases the results obtained are probably only an approximation to the truth. With these allowances, however, we may still obtain results which have some value and are not without interest.

From the point of view of hair-color and eye-color I have divided

British persons of genius into four classes: Fair (with blue or predominantly blue eyes, and light or brown hair), Mixed (with greenish, blue-yellow or blue-orange eyes,* and brown hair), Dark (hazel or brown eyes and brown or black hair), and a class of individuals belonging to the so-called 'Celtic type' (blue or gray eyes and more or less black hair). The Fair type includes 22 per cent. cases, the Mixed type 29 per cent., the Dark type 41 per cent., and the Celtic type 8 per cent. This result probably indicates that all the races occupying Great Britain—however we may define or classify those races—have furnished their contribution to British genius. The interesting and somewhat unexpected fact which emerges is the undue predominance of the Dark class, a predominance by no means exclusively due to Irish and Welsh influences, since very dark men of genius have been furnished by the Scotch Lowlands and the English eastern counties, where the populations are, on the whole, decidedly fair. This tendency is the more striking when we recall that the aristocratic class shows a tendency to fairness, and that our men of genius have been largely drawn from that class. It would be out of place, however, to discuss further the question of pigmentation.

While British genius is thus spread in a fairly impartial manner over the British Islands, and while all the chief physical types appear to have contributed men of genius, there are yet certain districts which have been peculiarly prolific in intellectual ability. In England there are two such centers, the most important being in Norfolk and Suffolk, and to some extent the adjoining counties; Norfolk stands easily at the head of British counties in the production of genius.† The other English center is in Devonshire and Somerset. In Scotland a belt running from Aberdeen through Forfar, Fife, the country round Edinburgh, Lanark (including Glasgow), Ayr and Dumfries is especially rich in genius. In Ireland the chief center (if we leave Dublin out of consideration) is in the southeastern group of counties: Kilkenny, Tipperary, Waterford and Cork; there is a less important north-eastern center in Antrim and Down.

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*It may be necessary to point out that eyes vary in color from unpigmented (blue) to fully pigmented (brown); between these two extremes we have various mixtures of blue with yellow or brown. The so-called 'black' eye is really brown.

† It may be noted that the founders of New England, both on the political and the religious sides, were mainly produced by this East Anglian center of genius. The people of this region are racially connected with the Dutch, and have always combined a genius for statesmanship and an aptitude for compromise with an inflexible love of independence. I may add that I have dealt more fully with some of the points touched on in this section in an article on the geographical distribution of British ability, shortly to appear in the *Monthly Review*.

III. SOCIAL CLASS.

In considering to what social classes the 902 eminent British men and women on our list belong, we naturally seek to ascertain the position of the fathers. In 262 cases it has not been easy to pronounce definitely on this point, and I have, therefore, classed these cases as doubtful. The remaining 640 may be classed with a fair degree of certainty. I find that they fall into the following groups: Upper Classes (or 'good family') 110 (12.2 per cent.), Yeomen and Farmers 39 (4.3 per cent.), Church 113 (12.5 per cent.), Law 49 (5.4 per cent.), Army 26 (2.9 per cent.), Medicine 26 (2.9 per cent.), Miscellaneous Professions 80 (8.9 per cent.), Trade 113 (12.5 per cent.), Crafts 63 (7 per cent.), Unskilled Workers 21 (2.3 per cent.), while the remaining 262 of doubtful origin constitute 29 per cent. of the whole. In a very few cases (not more than half a dozen) the status of the father is entered under two heads, but, as a rule, it has seemed sufficient to state what may be presumed to be the father's chief occupation at the time when his eminent child was born.

In the order in which I have placed the groups they may be said to constitute a kind of hierarchy. I place the Yeomen and Farmers immediately after the Upper Class group. Until recent years, the man who lived on the land which had belonged to his family for many centuries occupied a position not essentially different from that of the more noble families with somewhat larger estates around him. Even at the present day, in remote parts of the country it is not difficult to meet men who live on the land on farms which have belonged to their ancestors through several centuries. Such aristocrats of the soil, thus belonging to 'old families,' frequently have all the characteristics of fine country gentlemen, and in former days the line of demarcation between them and the 'upper class' must often have been difficult to draw. I have formed my 'upper class' group in a somewhat exclusive spirit; I have not included in it the very large body of eminent men who are said to belong to 'old families'; these I have mostly allowed to fall into the 'doubtful' group, but there is good reason to believe that a considerable proportion really belong to the class of small country gentlemen on the borderland between the aristocracy in the narrow sense and the yeoman and farmer class. To this class, therefore, must be attributed a very important part in the production of the men who have furnished the characteristics of British civilization.

The same must be said of the clergy (including dissenting ministers of all denominations), whom I place next because they are largely drawn from the same ranks and have on the whole led very similar lives. The religious movements of the past century have altogether transformed the lives of the clergy, but until recent years the parson was

usually simply a country gentleman somewhat better educated, more in touch with intellectual tastes and pursuits, than the other country gentlemen among whom he lived. The proportion of distinguished men and women contributed from among the families of the clergy can only be described as enormous. In mere number the clergy can seldom have equaled the butchers or bakers in their parishes, yet only two butchers and three bakers are definitely ascertained to have produced eminent children, as against 113 parsons. Even if we compare the Church with the other professions with which it is most usually classed, we find that the eminent children of the clergy considerably outnumber those of lawyers, doctors and army officers put together. This preponderance is the more remarkable when we remember that (although I have certainly included eminent illegitimate children of priests) it is only within the last three and a half centuries that the clergy have been free to compete in this field. Law, Medicine and the Army furnish contingents which, though very much smaller than that of the Church, are sufficiently important to be grouped separately, but all the remaining professions I have thrown into a single group. These are: Officials (Government officials, noblemen's stewards, clerks, etc.) 19, Artists (painters, sculptors, engravers, architects) 15, Actors, etc., 14, Musicians, Composers, etc., 8, Naval, etc., 8, Men of Letters 5, Schoolmasters 4, Engineers, Surveyors and Accountants 4, Men of Science 3. Although so few of the fathers of eminent men can be described professionally as men of letters or men of science, it must be added that in a considerable number of cases literary or scientific aptitudes were present.

We now reach a group of altogether different character, Trade. It is a group of great magnitude, but its size is due to the inevitable inclusion of a very large number of avocations under a single heading. These avocations range from banking to inn-keeping. The bankers evidently form the aristocracy of the trading class, and a remarkable number, considering the smallness of the class (not less than 8), have been the fathers of eminent sons. Under the rather vague heading of 'Merchants' we find 16, and there are 6 manufacturers. Wine merchants, brewers, vintners, publicans and others connected with the sale or production of alcoholic liquors have yielded as many as 13 distinguished sons, who have often attained a high degree of eminence, from Chaucer to Joule. Tea and coffee are only responsible for one each. There are 8 drapers, mercers and hosiers, and 6 tailors and hatters; grocers and a great number of other shop-keeping trades count at most 3 eminent men each. It is, perhaps, noteworthy that at least 4 Lord Mayors of London have been the fathers of distinguished sons; only one of them (Gresham) attained fame in business, the others becoming men of letters and scholars. It must be added in regard to this group that in a

certain number of cases the particular 'trade' or 'business' of the father is not specified.

The group which I have denominated 'Crafts' is closely related to that of 'Trade,' and in many cases it is difficult or impossible to decide whether an occupation should be entered under one or the other head. But, speaking generally, there is a very clear distinction between the two groups. The trade avocations are essentially commercial, and for success they involve, above all, financial ability; the crafts are essentially manual, and success here involves more of the qualities of the artist than of the tradesman. Just as the banker is the typical representative of commercial transactions, so the carpenter stands at the head of the crafts. There seems to be something peculiar in the life or aptitudes of the carpenter especially favorable to the production of intellectual children, for this association has occurred as many as 13 times, while there are 4 builders. No other craft approaches the carpenter in this respect; there are 5 shoemakers, 5 cloth-workers, 5 weavers (all belonging to the early phase of industrial development before factories), 5 goldsmiths and jewelers, 4 blacksmiths, while many other handicrafts are mentioned once or twice.

Finally, we reach the group of parents engaged in some unskilled work, and, therefore, belonging to the very lowest social class. It is the smallest of all the groups, and, though including some notable persons, it can scarcely be said to be a preeminently distinguished group. As many as 8 of the parents were common soldiers, the rest mostly agricultural laborers.

It may be interesting to inquire whether our eminent men, when grouped according to the station and avocation of their fathers, show any marked group-characters; whether, in other words, the occupation of the father exercises an influence on the nature and direction of the intellectual aptitudes of the son. To some extent it does exercise such an influence. It is true that there are eminent men of very various kinds in all of these groups. But there is yet a clearly visible tendency for certain kinds of ability to fall into certain groups. It is not surprising that there should be a tendency for the son to follow the profession of the father. Nor is it surprising that a great number of statesmen should be found in the upper class group. Men of letters are yielded by every class, perhaps especially by the clergy, but Shakespeare and, it is probable, Milton belonged to families of yeomen. The sons of lawyers, one notes, even to a greater extent than the eminent men of 'upper class' birth, eventually find themselves in the House of Lords, and not always as lawyers. The two groups of Army and Medicine are numerically identical, but in other respects very unlike. The sons of army men form a very brilliant and versatile group, and include a large proportion of great soldiers; the sons of doctors do not show a

single eminent doctor, and if it were not for the presence of two men of the very first rank—Darwin and Landor—they would constitute a somewhat mediocre group. It is an interesting, and I think a significant, fact that the fathers of as many as 25 artists exercised either a craft or some trade very closely allied to a craft. Great actors and actresses, more than any other group of eminent persons, tend to be of low, obscure or dubious birth; 4, at least, can be definitely set down as the children of unskilled laborers.

When we survey the field of investigation I have here very briefly summarized, the most striking fact we encounter is the extraordinary extent to which British men and women of genius have been produced by the highest and smallest social classes, and the minute part which has been played by the 'teeming masses' in building up British civilization. This is not altogether an unexpected result, though it has not before been shown to hold good for the entire field of the intellectual ability of a country.* To realize the enormous preponderance of the aristocracy in the production of these eminent men, and the oligarchic basis of British civilization, it must be remembered not only, as I have already pointed out, that a very considerable proportion of the 'Doubtful' group belong to 'old families,' which are certainly often 'good families,' but also that I have excluded altogether the children of peers, notwithstanding that they form a group which has played a very important part indeed in the national life. As we descend the social pyramid, although we are dealing with an ever-vaster mass of human material, the appearance of any individual of eminent ability becomes an ever rarer phenomenon, while the eminent persons belonging to the lowest and most numerous class of all are, numerically at all events, an almost negligible quantity.

One is tempted to ask how far the industrial progress of the nineteenth century, the growth of factories, the development of urban life, will alter the conditions affecting the production of eminent men. It seems clear that, taking English history as a whole, the conditions of rural life have been most favorable to the production of genius. The minor aristocracy and the clergy—the 'gentlemen' of England—living on the soil in the open air, in a life of independence at once laborious and leisurely, have been able to give their children good opportunities

*In Maclean's statistical study of the origins of British men of ability during the nineteenth century it is shown that 26 per cent. of those of known origin were sons of 'aristocrats, officials, etc.'; the result was almost identical when the 100 men of preëminent ability were considered separately. Mr. C. H. Cooley ('Annals of the American Academy,' May, 1897) investigated the point in regard to a group of distinguished European poets, philosophers and men of letters, and found that 45 belonged to the upper and upper middle classes, 24 to the lower middle class, and only 2 to the lower class.

for development, while at the same time they have not been able to dispense them from the necessity of work. Thus, at all events, it has been in the past. How it will be in the future is a question which the data before us in no way help to answer. So far as can be seen, the changing conditions of life have as yet made no change in the conditions required for producing genius. Life in the old towns formerly fertile in intellectual ability—towns like Edinburgh, Norwich, Bury St. Edmunds and Plymouth—was altogether unlike life in our modern urban centers, and there is yet no sign that the latter will equal the former in genius-producing power. Nor is there any sign that the education of the proletariat will lead to a new development of eminent men; the lowest class in Great Britain, so far as the data before us show, has not exhibited any recent tendency to a higher yield of genius, and what production it is accountable for remains rural rather than urban.

DISCUSSION AND CORRESPONDENCE.

RANDOM REMARKS OF A LADY SCIENTIST.

To the Editor: I am a lady scientist, and I suppose you will think it very rude in me to intrude what I think into the grand affairs of a great scientific magazine. But I really must say to you that it is very shameful of you to encourage Mr. Starr Jordan to indulge his fiendish delight in depreciating feminine science—Karyokinesis. I feel his attack bitterly, for after passing an examination—equal to that described by Monsieur Arago in his Autobiography, during which a bright young man of more than usual assurance even for a Frenchman was so put upon by old Mr. Monge, the mathematician, that he fainted and had to be carried out past Mr. Arago and the other gentlemen in the antechamber on a shutter—in astronomy, geology, chemistry, physics, meteorology both in the past perfect and future indicative, mathematics and sociology, I obtained my present position as copyist at $480 per annum in the Direction of Science, Division of Karyokinesis.

I do not believe at all in this ex-post-facto theory of abolishing time and space, which is unconstitutional, anyhow, because it is forbidden by the Declaration of Independence and is imperialism. Now, I am going to take Mr. Starr Jordan up, word for word, and show that he is simply ridiculous.

Telepathy is a pure science. It is pure because it was a woman who invented it. No man could ever have had the sense to get up such a science. A man's intellect is fatally defective. You positively can not make it comprehend that if everybody stops doing drudgery because the world is an oyster, things will go on just the same, if not better. I know there are exceptions, but such exceptional men are really, speaking psychologically, women, and may for convenience of reference be called Untermenschen; and probably Mr. Alexander Dumas, fils, was describing one of these gifted minds in his charming moral story where Count Petit Lavellère de Château-Bourbon capers about the sleeping-apartment of Madame Revocation de la Tour de Nesle on all fours like a spaniel, with her real point-lace handkerchief in his mouth.

Compare the delicate suggestiveness of this beautiful picture with the coarse vulgarity of a vile Scot's lord at a card party when his partner, the Viscountess Smith, played the wrong card. "You old bitch," roared the *noble (!)* lord, "what did you play that card for?" And then, recalled to his environment by the look of astonishment on her ladyship's face, he blurted out: "Your pardon's begged, mum. I thought I was speaking to me wife," just as though that poor woman was his 'chum.'

Of course, at this stage of scientific expansion it is impossible to rear every man as an *Untermensch*, as we should be able to rear him were we in possession of the universities, and like he is reared in the seraglio by the eunuchs and the ladies of the harem so quaintly pictured by Lord Byron, a man of strong Turkish characteristics, in his sweet tale of Don Juan. When, however, advancing civilization has discredited the vague and unsatisfactory principle of evolution or the survival of the fittest or force science for the immediate and visible principle of Karyokinesis, or egg science, which depends on hatching and not on principle, however, then the strange notion that the meaning of childhood is to give time to live through the history of the race will be discarded, and it will be openly taught that a child goes

through this time-killing process in its own mother's bosom, and that telepathy is, therefore, particularly a feminine science, as it is only a woman who can write history based on original facts at the rate of 40,000,000 years in nine months. When the world has been brought to respect the true literary function of woman, then she will recognize her duty to rescue history by properly editing her historical productions on the part consecrated by immemorial usage to that purpose, and not till then.

Now, I must say that I think all this fault-finding about instrumentation is just too silly for anything; but I don't think Mr. Starr Jordan is as bad as some other people I know. It always seemed to me that some of these men, perhaps even the married ones who live in a far, far away State, are just put out because so many pretty girls, and as many ugly ones as could ring in, *crowd* around the telepathic *savant* and *never* go near *them*. But I am not speaking of the vanity of men, which is simply immense; for, as in the Dark Ages, devoted women fled from the brutality of the world and vowed their maidenhood to Heaven in a nunnery, so I have vowed myself to science in the Division of Karyokinesis.

Men have their principia as a starting point in their 'science of brains,' as I suppose they would call it, and it winds up in the 'conservation of energy'; and now they are trying to find out the meaning of a star's childhood which it passes in the Milky Way, just as though that wasn't the proper place for an orphan to be born in. Women have their Karyokinesis for a starting point and wind up in telepathy. Where is the difference? Our science is older than theirs as a philosophy. What is the meaning of chivalry but adoration of Karyokinesis? What is the cell theory but chivalry materialized? Well might the genus beautifully symbolized as the slave of the lamp in Aladdin's Wonderful Lamp kick up such a row when Aladdin wanted an egg put under the skylight of his palace.

The feminine in science acknowledges no master save caprice—whim and an Uebermensch. Yet, while on the surface it is Uebermensch enthroned, beneath all is an unstable equilibrium caused by would-be Uebermenschen who are exploiting the wide interval between the reigning Uebermensch's promises and his performances. This is the basis of Karyokinetic sociology. Pious wishes, not natural laws, is its normal motto, and each for himself and the devil take the hindmost is its only possible principle of action. The 'psychology of the mob' thus is lifted from a subordinate to a primary social fact, and comes to mean the same as though it read 'the psychology of fashions,' which are supposed to be made in Paris. It is very absurd to hear the man intellect vaporing about the great social axioms which a self-perpetuating society *must* obey, and the rule of action which a *manly* and only possibly true non-imperialistic people *must* try to follow out if it wishes to stamp out imperialism, and the so-called 'laws' which your stick-in-the-mud scientists are formulating at a snail's pace—laws which 'prove' the accuracy of these 'majestic' generalizations of Moses and of Jesus. No, the feminine in science demands immediate, up-to-date facts, or, if it will afford Mr. Starr Jordan any satisfaction, hysterical theories for its inductions, and these are furnished by telepathy, which, like every dramatic science, requires scenery and stage furniture, so as to be able to tell the past by the actual *me*, the cogito ergo sum automaton, not by the interrogation of invaluable sequence and stuff.

Seated upon his stage, surrounded by a painted vale of Italian softness and bathed in an atmosphere of amorous music and perfumes, with soft couches that invite the drowsy indolence that crawls upon the intellect, the telepathic physiological psychologist or Uebermensch can not, it is true, get ahead of the future; but he can get behind the past; he can annihilate time, he can annihilate space, for by the magic power

of his resistless will he can make the cells of the nervous system retrokaryokinetate to the period when they opened and shut a bivalve or sojourned upon the planet Mars. This, then, is the difference between a telepath and a charlatan: the charlatan is a broker who deals in futures; the telepath is a commission merchant who deals in eggs.

REBECCA SHARPE.

P. S.—As I go over this to put in missing commas and words, it seems to me that it is made up crazy quilt patchwork fashion, so I suppose it is hardly a virtue to say that, though I first mixed it all up and then wrote it out of my own head, I got the woman facts from old Mrs. Blackleg, who keeps the boarding-house where I lodge, and the sociological facts from a poor fellow who is madly in love with me and has proposed ever so many times, though I have never given him the slightest encouragement, no, never; but he will, and he will, and he will. Not that I am no scientist and don't know original facts. That is not true, for when I was studying up for examination I noticed how the jellyfish Medusa could easily heal its wounded nervous system, and the starfish, too, and so needed no protection, as every part could go off on its own hook; and then how Nature, in making a more centralized nervous system, made a limestone coat for the poor thing, and so on, until I, trying to work out the puzzle of mental fatigue, found that the dear old lady made a clean jump to a double nervous system for backbone animals, one set for vascular work and the other for fighting purposes, and brains made ribs of the entrenchment of the clam and the cuirass of the turtle. And without bothering you any more, I only want to say that when man and woman were somatically one, and when, for purposes best known to a wise and unscrupulous Providence, they somatically became two, that woman remained mankind and nearer to nature, and man must be regarded as a mere *freak*, which accounts for his ridiculousness and his 'laws,' which are the dread enemies of the worship of Karyokinesis. But I forget all this when riding home in the cool evening air, and the electric car goes bobbing up and down as it tears down the hill, and I hug up close to that broad-shouldered social wretch who is fighting Mrs. Blackleg and her telepaths for my happiness.

CHRISTIAN SCIENCE.

To the Editor: It certainly has been sufficiently obvious, by the communication of Mr. Smith in your February issue, that the means of thought-communication between 'material scientists' and 'Christian Scientists' are by no means easy or adequate. Not being able to rise above 'human logic,' I am placed along with many other worthies, in whose company I take pride, amongst the 'materialists,' and am accordingly and very properly reminded that my opinion on matters pertaining to religion and to Christianity are of little consequence. Let it be also noted *en passant* that I am not regarded as having attacking 'Christian Science,' but only credited with the belief that I thought I had. Consistently with their own doctrines this really should amount to the same thing. So it will be well to disclaim any intention of attacking, in the personal sense which your correspondent gives to the discussion, the upholders of this or any other faith. It is always important to keep in mind the admonition of Huxley that in controversy one should not wander from the really essential question of what is right and what is wrong to the entirely unimportant matter of who is right and who is wrong.

But my main purpose in sending this note is to protest against the assumption of my critic that the representatives of Christianity are arrayed with him and against me in the advocacy of certain doctrines which I insist are not characteristically religious ones, and which, if they are distorted into a religious guise, can not by that shift escape the candid comment of commonsense science. It is an injustice to the

representatives of Christian faiths to put them, by implication or assertion, in the position of giving support to tendencies which they have an equal interest with the expounders of science in opposing. I shall content myself with one quotation from an authoritative source—Bishop Fallows, of Chicago—which places this dubious attempt to mingle religion with unscientific medical dogmas in the only light in which right-minded persons of whatever training can complacently look upon it.

"If my good friends," says the Bishop, "are going to start, or believe in a professed religious system because they have been healed through the influence of a mental law as universal as gravitation, the people who have been cured by patent nostrums have just as much reason to establish a religious cult of Christian liver pillists, Christian Sarsaparillists, Christian Celery Compoundists, or Christian Cholera Mixturists, as had Mother Eddy to found a church of Christian Scientists. 'By their fruits ye shall know them.' I do know some of the best Christians living who believe with unshaken faith that they were cured by these patent nostrums. But they have had the good sense to remain in the church and not claim a special dispensation for the discoveries of their favorite patent medicines."

JOSEPH JASTROW.

University of Wisconsin.

THE INVENTOR OF THE SEWING MACHINE.

To the Editor: In the November POPULAR SCIENCE MONTHLY the munificent gift of Miss Helen Gould for a Hall of Fame is noticed, and thirty names are designated as the choice of certain prominent men (not named) for place therein as the most eminent Americans.

In the list given the name of Elias Howe appears, which must produce astonishment in the minds of every one who has a knowledge of him or of the history of the sewing machine, upon which alone his claim to notoriety rests. To all who are acquainted with the advent of that machine, Howe occupies a very minor place. Patents were granted for such machines long before Howe entered the field, and he never succeeded in producing a practical machine, until more than one device invented by others was added to it.

Several inventors were striving to make a practical sewing machine, which was finally accomplished on different lines by some of them. The fact that Howe received royalties from these men, who procured the extension of his patent, was a matter of policy that we pass as irrelevant to the question of the introduction of this great public acquisition, in which he took no active part.

Howe was not a first-class mechanic, and the devices he patented were all elaborated before him by others, and not until other important devices were added did the sewing machine come into use. To place his name on the roll of fame above a host of his superiors on the records of the Patent Office would be doing American genius a grave injustice that would render the Hall of Fame absurd. I trust no such radical mistake will be perpetrated.

VINDICATOR.

SCIENTIFIC LITERATURE.

THE FOUNDATIONS OF KNOWLEDGE.

LITTLE doubt can exist longer that the coolness which marked the relationship between Science and Philosophy from about 1840 until within the last decade is passing away rapidly. Thanks partly to the development of experimental psychology, partly to the broader training given at our colleges, where science has won a recognized place in the undergraduate course, the younger men who specialize in philosophy possess some acquaintance with the scientific attitude and temper. To them, and to the professed votary of science, the new work, entitled 'Foundations of Knowledge,' by Professor Ormond, of Princeton (Macmillan), can not fail to present some attractive and some curious considerations. In witness of his sympathy with the modern outlook, and to a certain extent under pressure of its demands, the 'McCosh Professor,' of all people, has striven hard to adopt an experiential basis. He sees quite clearly that neither the hide-bound empiricism of the traditional English school, nor the vaulting *a priori* dialectic of Hegel and his English-speaking derivants, suffice to philosophical salvation at present. Accordingly, he has provided a sober, straightforward analysis of the implications hidden under such terms as Experience, Knowledge, Reality. This forms the First Part of his essay. Having thus expelled traditional subjects of contention, he proceeds to consider the various characteristic ways in which knowledge grows from a less to a more complex synthesis of things. In this connection, he deals with the same material upon which metaphysicians have racked their brains time out of mind—Space, Time, Quantity, Quality, Cause, Substance, taking the stage successively. And it must be said that, although Professor Ormond's style is a trifle heavy, he contrives to set forth some sensible, fresh and, moreover, plain conclusions. But, as has been hinted, these matters are ancient history with all philosophers, as with some scientific workers. And so, this Second Part of the work does not stop here. As many are aware, the ideas just mentioned may be called static; and the modern tendency—very strong in science, equally strong with the younger philosophical men—makes its presence felt in Professor Ormond's discussion of dynamic aspects of experience. The conception of a social mind, leading to the ideas of relationship, interdependence and unitary mental life expressing itself in individuals, has attracted his close attention. It can hardly be said that he has embraced all the conclusions to which such conceptions lead necessarily. He makes reservations, or rather, the habit of his mind and the influences of his education induce him to stop short midway in his progress. Consequently, it turns out, in the Third Part of the book, that human experience possesses a 'transcendent or superordinary element.' Here, it seems, philosophy finds its peculiar work, while science deals with the ordinary or relative. Even a superficial acquaintance with the history of thought reminds us that this is a very old idea; one, too, which, like other old ideas, has been petarded often. But Professor Ormond presents it in a fresh way, and in as reasonable fashion as it is capable of assuming. Not that he justifies it, for it cannot be justified, except by Deity. At the same time, through its instrumentality he calls attention to one aspect of knowledge that has been subject to neglect of late. From this brief

outline, the reader will gather, *first*, that the book possesses a certain originality of its own, it stands for solid work by its author and affords one the pleasure that such work gives. *Second*, it is attractive, because it marks a stage of transition. Ten years hence, these clean-cut distinctions within experience will have become impossible. The work is, therefore, to be commended as a faithful and forthright representation of that type of thinking which, though well aware of the futilities of eighteenth century dualism, has not yet awakened to the demands of twentieth century system. Being thus a type, it is well worth taking into consideration.

STATIONARY RADIANTS TO SHOWERS OF SHOOTING STARS.

THE radiant of a shower of shooting stars is the point or area from which all the stars appear to move when perspectively projected on the celestial vault. If the tracks of a shower of meteors are laid down on a star map, and if these tracks are prolonged, all of them will intersect in a point, or, at least, within a small area—the radiant. The meteors are really moving in parallel straight lines in space. Their paths are perspectively projected into great circles of the celestial sphere, and have a common vanishing point. The case is easily understood by that of the 'sun drawing water,' which is often seen about sunset. The rays of the sun are really parallel, but they seem to radiate in all directions from the sun's disc in great circles that have a common vanishing point.

This perspective theory demands that the radiant point of a shower of meteors should rise, culminate and set by the earth's diurnal motion, precisely as the sun, or a star, rises, culminates and sets. The meteors on any night do, in fact, radiate from spots which remain fixed among the stars, and which rise, culminate and set as do the stars themselves. If the shower continues for many nights (like the Perseid shower, for instance) the place of the radiant usually shifts among the stars, as it ought to do, since its position is due to a geometric configuration which changes as the earth moves. The perspective appearances change as the place of the spectator is altered by the earth's motion in its orbit. Mr. W. F. Denning, of Bristol, England, an experienced and assiduous observer of meteors, reports that he has found cases where the appearances differ from these normal conditions. For certain showers of meteors, the radiant does not change its place among the stars as the earth moves in its orbit, but, on the contrary, the radiant remains stationary for weeks. A typical case of the sort is the shower of the Orionids. This shower persists for about two weeks (October 10-24), and the radiant remains stationary near the star υ Orionis, instead of shifting with the earth's motion as the laws of celestial perspective demand.

No satisfactory explanation of such stationary radiants has been forthcoming; and many astronomers have doubted the correctness of Mr. Denning's observations on that account. Granting that the observations are correct, an explanation of the phenomenon has been given by Professor von Niessl, of Brünn, and this explanation was briefly reported by Prof. Alexander Herschel at a recent meeting of the Astronomical Society of France. From a rather meager account of the report it appears that M. von Niessl has sought for a path of a meteor stream so situated in space and so curved that the observed phenomena would necessarily follow. Given the phenomena and the fact that they are produced by the perspective projection of the actual paths of meteors in space, he has inquired what the paths must be to satisfy all the conditions. If we assume swarms of meteors, moving with small velocities in space, in hyperbolic orbits nearly parallel, the orbits being asymptotic to the sun, meteors proceeding from such swarms would seem to have a stationary radi-

ant. Moreover, such meteors must originate in certain fixed emissive centers in the stellar regions (beyond the solar system). The phenomena for certain aerolites whose fall has been observed are accounted for by reasonable assumptions as to the existence of the cosmical centers of emission, primitive velocity and direction.

Without seeing M. von Niessl's original paper it is impossible to give more than the foregoing brief report. It is obvious that if we assume a set of centers of emission exterior to the solar system, and suppose that they send out swarms of meteors which, in time, reach the solar system, it is possible to make reasonable assumptions as to velocity, etc., that will account for all the observed phenomena. A geometrical explanation of stationary radiants can be had in this way. It is not yet possible to say whether there is sufficient physical evidence to make the existence of such extra-solar emissive centers probable. All that can now be done is to report this essay towards a physical explanation of a very puzzling phenomenon.

THE UTILIZATION OF FOOD AND ALCOHOL IN THE HUMAN BODY.

WIDESPREAD interest has been taken in the results reported by Prof. W. O. Atwater on the food value of alcohol. These alcohol experiments constitute a part of a series of experiments on the utilization of food in the human body which have been in progress for a number of years. A technical description of a number of them forms a part of a bulletin by Professor Atwater *et al.* on 'The Metabolism of Matter and Energy in the Human Body,' just issued by the United States Department of Agriculture. The bulletin describes in detail fourteen experiments carried on with human subjects in the Atwater-Rosa respiration calorimeter. It presents additional data bearing upon the metabolism of matter and energy in the human body under conditions of rest and work, the conservation of energy under these conditions, the action of the ordinary food nutrients in the body, and the effect of muscular work upon nitrogen metabolism.

The aim in these experiments was to furnish the subject with approximately the quantity of nitrogen, carbon and energy in the basal ration that would be required to keep him in nitrogen and carbon equilibrium. This was practically attained. Upon the addition to the basal ration of an amount of alcohol or sugar furnishing approximately 500 calories of energy per day, it was found that the body appeared to store an amount of fat having practically an isodynamic value with the alcohol or sugar eaten. It is doubtful whether all the energy in the sugar was actually available to the body, some loss being sustained in transferring the sugar from the alimentary canal into the circulation. Assuming 98 per cent. of the energy of the sugar to be actually available to the body, it is calculated that this would give 505 calories of available energy furnished by the sugar, and 477 calories of extra fat stored by the body, as compared with the preceding experiments upon the basal ration.

The close agreement between the quantities of heat actually determined and the theoretical amounts furnished by the materials actually oxidized in the body is one of the interesting features of the experiments, and indicates the degree of accuracy which has been attained with the apparatus and the methods employed.

An important scientific result of these investigations thus far has been to demonstrate, in a manner which has never been done before, the application of the law of the conservation of matter and of energy in the human body.

The report is largely one of progress. The authors propose in future experiments to study further the metabolism of different classes of nutrients and the relative replacing power of the energy as furnished by different materials.

THE PROGRESS OF SCIENCE.

In the numerous reviews of the nineteenth century published in the magazines and in the daily press, science occupies the most prominent place. The news of the world for a day, as we read it in the newspaper, or for a month, as given in certain journals, may contain no reference to science, yet the contemporary events which at the time excite such general interest are forgotten, while the quiet progress of science gradually emerges in its true proportions. The century witnessed other great achievements—music in Germany, poetry in England, the novel in France, Russia and England—but these are like royal palaces, beautiful and complete, more likely now to decay than to grow. Science, on the other hand, has laid the foundations on which the future rests. The applications of science to the arts and to commerce, permitting one man to do what formerly required ten, and giving more nearly than ever before to each the return of his labor, have made modern democracy possible. The methods of science, slowly spreading and exerting their control, have made democracy comparatively safe. The results of science will help to make democracy worth the while. Thus, to take an example, there is now sufficient wealth to permit the education of each child; scientific methods will ultimately determine how he shall be educated, and science offers the material to be used in the training. It may be that we shall some day arrive at a scientific scholasticism, for atrophy and degeneration are no less real than growth and progress, but it seems probable that the history of the twentieth century will be chiefly a history of science.

The death of Queen Victoria closes an era in the history of a great nation; but, like the century, it is a somewhat artificial period. The monarchy in Great Britain is primarily a social institution, and it does not appear that the Queen exerted any influence on the development of science, except in so far as her sane and kindly character tended to maintain the peace and morality that are favorable to science. The death of the Prince Consort, forty years ago, was a distinct loss to science, for he was interested in scientific and educational problems, and showed in the case of the Exhibition of 1851 that he could exert powerful influence on their behalf. Queen Victoria was a German woman of domestic and religious type, and she was doubtless ignorant of the contributions to the physical sciences made by her subjects, while she regarded with aversion the advances in the natural sciences due to Darwin. Still, in the social heirarchy, of which the Queen was the head, science was recognized to a greater extent than ever before. Lords Kelvin, Lister, Playfair and Avebury were elevated to the peerage wholly or in part for scientific work, and minor titles have been conferred in many cases. Scientific men occupy a higher social and political position in Great Britain than in the United States, and this has been an outcome of the Victorian Age. It is not, however, due to the favor of a court, but to the great men of science of the period, and to the fact that many of these belong to the higher social classes. King Edward VII. will preside with dignity at scientific functions, but it is not likely that he will attempt to exert an active influence on behalf of science. Still, he was educated under the direction of a scientific man, Lord Playfair, and he is said to be well informed in the sciences. It is possible that he will not only give the social recognition which is not with-

out value, but will, like the late Prince Consort, favor the direct encouragement of science by the Government.

A PROPHET is not needed to tell us that the relations between the Government and science will be closer in the twentieth century than ever before. Hundreds of millions of dollars are now annually spent by the leading nations in preparing for wars which may not occur, while only a small provision is made for the industrial wars continually in progress. In spite of recent events, it is likely that wars with ships and armies will gradually cease, and, while they continue, the results will depend increasingly on industrial and scientific factors. It is not so important for us to own warships as to know how to build and man them. It is not so essential to alter the rifle each time an improvement is made as to be able to invent and make the best rifle when needed. But supremacy among the nations no longer depends chiefly on performance in time of war. The rivalry in trade and manufactures, the struggle for material success and intellectual preeminence has become increasingly severe. As one species has supplanted another, not so much by directly opposing it, as by fitting itself better to the environment, so that nation will now survive and supplant others which is best able to adjust itself to existing conditions. First in importance are certain moral qualities which at present the State can not greatly forward; but next after these are the training and efficient use of intellectual traits, and here much can be accomplished by proper organization and the offering of opportunity. In the United States the establishment of unrivaled scientific and educational institutions would have an important function in unifying the nation and giving expression to its spirit. The patriotism and loyalty which in Great Britain find their emblem in the monarch must here seek other expression. They could take no better form than pride in the scientific and educational institutions of the nation.

As a matter of fact, the United States Government does make larger provision for scientific work than any other nation. The bills now before Congress will assign to this purpose perhaps $9,000,000. This is by no means a small sum, yet it is only 12 cents from each of us, and there is every reason to advocate its increase as rapidly as men can be found to whom the money may be safely entrusted. The Department of Agriculture and the Geological Survey have earned the confidence of the country, and their appropriations will be increased. Thus the House has approved an item allotting an additional $100,000 to the Division of Forestry. It is probable that the arts and manufactures would profit more by the establishment of a department corresponding to the Department of Agriculture than by the continuation of a protective tariff. A step in this direction will doubtless be made by this or the next Congress in the authorization of a National Standardizing Bureau. The bill has been approved by committees of the Senate and of the House, and only pressure of other business is likely to interfere with its immediate adoption. As we have already explained, the United States is in this direction far behind nations with smaller resources, and it is satisfactory to know that this state of affairs will not long continue.

THERE are two directions in which the appropriations of the Government for scientific work should be increased, and there are special reasons why these should be urged by men of science not engaged in the Government service. We refer to proper salaries for certain of the scientific men at Washington and the adequate support of the United States National Museum. It is unwise for scientific men employed by the Government to ask for an increase of salary, as they thereby lose influence and are regarded as self-seeking. A strong presen-

tation of the unfairness of the present state of things should be made by those unconnected with the Government service. Every business man knows—and Congress is largely composed of able business men—that it is unwise to pay inadequate salaries to those who fill responsible offices. Thus the present agricultural appropriation bill, as approved by the House, allots $187,520 to the Division of Forestry, of which $2,500 is for the salary of the chief. Now the efficiency with which this large sum is expended depends on the chief, and it is clearly economical to secure the services of the best man in America. Such men are found, attracted by the great opportunities for advancing science offered by the Government service, but they are often called away to other work of equal importance with larger salary. Thus an officer of the Department of Agriculture receiving $1,800 has this year accepted a position under the Japanese Government with a salary of $7,000. Men from the Government bureaus will be found in all our universities, while it is but seldom that a man will go from a university position to Washington. The present agricultural appropriation bill contained a modest increase of salary for some of the scientific officers, but the provisions were regarded as out of order on the ground that they were new legislation. It is to be hoped that a bill will be introduced at once containing these provisions for the reorganization of the Department of Agriculture.

THE needs of the United States National Museum should be urged by men of science throughout the country, because its organization is such that it has no really responsible head, whose duty it is to present its claims to Congress. The museum has developed under the Smithsonian Institution, but, as Joseph Henry pointed out, the functions of the two institutions are entirely different. It may possibly be best for the museum to remain under the Smithsonian Institution, owing to administrative reasons; but it should at least have the autonomy possessed by the Bureau of American Ethnology with an independent director. The sheds in which the great, though somewhat unsymmetrical, collections are housed at Washington are a reproach both to science and to the Government. New York City has spent millions of dollars on the building for its museum, while the National Government has done practically nothing. Every member of Congress takes pride in the National Library, and no one regrets the millions of dollars that it cost. It is but right to give material expression in the best form possible to the intellectual life of the nation. But why should not the museum have a building equally representative, and funds for the increase of its collections by well-organized scientific expeditions? It will doubtless have them if we wait long enough, but there are more efficient ways to obtain things than by waiting.

SENATOR MORGAN has introduced a bill establishing a National Observatory of the United States on almost exactly the lines recommended in the last issue of this journal. There is now a real opportunity to secure a reform, advocated for years by our leading astronomers, and all interested in science should unite in urging the passage of the present measure. The text of Senator Morgan's bill is as follows:

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the United States Naval Observatory shall hereafter be known as the National Observatory of the United States and shall be governed by a director thereof, who shall report directly to and be under the supervision of the Secretary of the Navy.

Section 2.—That the Director of the National Observatory shall be an eminent astronomer, appointed by the President, by and with the advice and consent of the Senate, at a salary of five thousand dollars per annum, and shall be selected from the astronomers of the National Academy of Sciences unless, in the judgment of the President, an American astronomer of higher scien-

tific and executive qualifications shall be found.

Section 3.—That the Secretary of the Navy may detail for duty as astronomers at the National Observatory such professors of mathematics and other officers of the Navy as he shall deem necessary in the interests of the public service; but on and after the passage of this act no appointments shall be made of such professors unless required for service at the Naval Academy.

Section 4.—That there shall be a Board of Visitors of the National Observatory, to consist of one Senator, one member of the House of Representatives, and three astronomers of eminence, to be selected by the Secretary of the Navy. The Board of Visitors shall make an annual visitation, or more frequent visitations, of the Observatory, advise with the director thereof as to the scientific work to be prosecuted, and report to the Secretary of the Navy on the work and needs of the observatory on or before the first day of November in each year. The members of the said board may receive an allowance not exceeding ten dollars per day each during their actual presence in the city of Washington while engaged on the duty of the board, and their necessary traveling expenses; but no officer of the Government appointed on the board shall receive any additional compensation for such duty above his actual expenses.

THE probability that a National Standardizing Bureau will be authorized by the present Congress adds interest to the plans of the National Physical Laboratory recently established in Great Britain. Experimental work, somewhat limited in character, has for a long while been carried on at Kew Observatory, and it was hoped that the new laboratories might be erected near by. Plans were drawn up for a physical building to cost $30,000, and an engineering building to cost $20,000. There was, however, opposition to the erection of these buildings in the Old Deer Park, and in October the Government decided to assign to the laboratory Bushey House and the surrounding grounds, 25 acres in extent. The building as it now stands will be turned into a laboratory for the more delicate measurements, and a new laboratory for engineering will be erected. The work that it is proposed to carry out, as soon as the buildings can be occupied, includes the connection between the magnetic quality and the physical, chemical and electrical properties of iron and of its alloys, the testing of steam gauges and various kinds of springs, standard screws and electrical measuring instruments, and optic and thermometric determinations. These subjects have an evident connection with trade and industry, and there is every reason to suppose that the cost of the laboratory will be saved many fold every year by economies in the arts and manufactures, while at the same time physical measurements can be carried out in an institution of this character which no university would be likely to undertake. It should be noted that the National Physical Laboratory is under the direct control of the Royal Society, which insures the highest attainable degree of efficiency.

A VALUABLE contribution to the study of the inert gases of the atmosphere is made by Professors Liveing and Dewar in a paper read before the Royal Society on December 13. The gases were obtained by liquefying air by contact with the walls of a vessel at atmospheric pressure cooled below 200° C. Some 200 ccm. of liquid air were thus condensed, and the more volatile portion was then distilled over into a receiver cooled with liquid hydrogen. This portion, consisting of about 10 ccm. was then passed into spectrum tubes, first, however, traversing a U-tube immersed also in liquid hydrogen. In this manner the gas was completely freed from every trace of nitrogen, argon and compounds of carbon. The tubes showed the spectra of hydrogen, helium and neon with great brilliancy, but also a large number of lines which could not be referred to any known origin. This shows conclusively that a sensible proportion of hydrogen exists in the earth's atmosphere, a point which has been much disputed in the past. If it be true,

as has been shown mathematically, that owing to the velocity of the hydrogen molecule, the earth cannot retain this gas in its atmosphere, then there must be a continued accession of hydrogen to the atmosphere from interplanetary space. If this is the case, it is probable that there must be a similar transfer of other gases, and therefore the authors of the paper sought in the spectra evidence of the presence of the characteristic lines of the spectra of nebulæ, of the corona, and of the aurora. Nebular lines were found in the tubes as above prepared; but in one, the gas of which had not been passed through the U-tube, and which contained traces of nitrogen and argon, a line was found very close to the principal green nebular ray, which did not appear in the other tubes, and which may indicate that the substance that is luminous in the nebulæ is really present in the earth's atmosphere. Several lines were found which may possibly be referred to coronal rays, but further study is necessary before this can be established. Still, more doubt attaches to the auroral rays, one of which seems to be identical with a strong ray of argon. The ingenious method devised for the collection of the gases, the demonstration of the presence of hydrogen in the atmosphere, and the possibilities opened up by this manner of attack render this research notable.

THE progress which has been made in recent years in determining the useful and injurious dairy bacteria, and the means of controlling their growth, has greatly promoted the intelligent production and handling of milk for household consumption and in butter-making. In this work a number of the agricultural experiment stations have taken an important part. The Storrs Experiment Station in Connecticut is among this number, and its twelfth annual report, just issued, gives an interesting résumé of the something over two hundred types of bacteria which Professor Conn has found in dairy products during the ten years he has been engaged in this work. On the basis of his studies he proposes a classification of dairy bacteria. Although the total number of species found in dairy products is large, only a comparatively few occur with very great regularity. Professor Conn concludes that those of the region represented by his investigations consist chiefly of three groups of closely related bacteria. Of these the most abundant are *Bacterium acidi lactici* I. (Esten) and *B. acidi lactici* II. (new species), which constitute the first group. The former occurs almost universally in milk and cream, is nearly always present in sour milk, and has been found by far the most abundant in all samples of ripened cream examined. The second form, while very abundant in sour milk and cream, occurs in less numbers. Several of the pure commercial cultures for ripening cream in butter-making consist of bacteria of this type. The next most important group is represented by a species regarded as identical with *B. lactis aerogenes*, and includes a number of types of great similiarity, but with different physiological characters. It has been found almost universally in milk, but never in very great numbers. Some of the pure cultures used in Europe for cream ripening appear to belong to this group. Typical sour milk, with its tendency to fragmentation and its sour odor, Professor Conn thinks, is never developed without the aid of some of the organisms of this group. The third type is the *Micrococcus lactis varians* of the author. It is common in fresh milk, and is thought to exist in the milk ducts, which is not the case with the preceding types, the source of contamination with which is believed to be entirely external. It is commonly overgrown by the lactic organisms and is less common in old milk. While the classification of dairy bacteria is regarded as necessarily a tentative one, it is offered as a basis for bringing together the work of American dairy bacteriologists.

ANOTHER paper in this report bearing on the subject of dairying relates to

the use of milk of tuberculous cows—a matter of more than usual interest in view of the attention which is being given to the general subject of tuberculosis and its transmission. Experiments in using the milk of tuberculous cows for feeding calves at the Storrs Station have been in progress for several years. During the first two years, when the cows had the disease only in its earliest stages, the young cattle which received their milk and ran with them constantly, exhibited no signs of the disease as far as could be detected by the tuberculin test or physical examination. But the result for the next year and a half was quite different. Five calves were fed the milk of these same cows, and all five responded to the tuberculin test and proved to be diseased. The physical condition of three of the cows indicated that during the last year the disease had progressed decidedly in them. While the results indicate that the danger from the spread of tuberculosis to other animals through the milk is not always as great as has been supposed, they suggest the exercise of greater precaution in excluding from use for supplying family milk all cows in which the disease is sufficiently advanced to be detected. Experiments at a number of places have shown that the milk of tuberculous cows may be pasteurized and safely used for raising calves, but precautions should be taken to insure confining its use to this purpose.

PROFESSOR E. C. PICKERING, director of the Harvard College Observatory, has been awarded the gold medal of the Royal Astronomical Society.—The Helmholtz medal of the Prussian Academy of Sciences has been conferred on Sir George Gabriel Stokes, of Cambridge University, this medal having been previously conferred only on Professor Virchow and Lord Kelvin.—Sir Archibald Geikie has retired from the directorship of the Geological Survey of Great Britain and Ireland.—We note with regret the death of Elisha Gray, the American inventor; of M. Ch. Hermite, the French mathematician; of Professor Max von Pettenkofer, the bacteriologist; of Frederic W. H. Myers, secretary of the Society for Psychical Research; and of Miles Rock, the American geodesist.—The International Zoological Congress will hold its fifth session in Berlin, beginning on August 12.—The Astronomical and Astrophysical Society of America will hold its next meeting in December.—William H. Crocker, of San Francisco, has offered to defray the expenses of a solar eclipse expedition to be sent by the University of California from the Lick Observatory to Sumatra to observe the total eclipse of the sun on May 17.—A bill has been introduced in the House of Representatives directing the general Government, through the Secretary of the Interior, to secure title to the cliff dwellers' region of New Mexico for park and scientific purposes, and one in the Senate appropriating $5,000,000 for the purchase of land in the Appalachian Mountains for a national forest reserve.—Mr. Joseph White Sprague has left his estate, valued at $200,000, so that it will ultimately revert to the Smithsonian Institution.—Johns Hopkins University has received a conditional gift of land for a new site valued at $700,000.—The French and German generals have removed from the wall of Pekin the superb astronomical instruments erected two centuries ago by the Jesuit fathers, and propose to send them partly to Berlin and partly to Paris. The American general has protested against this as an act of vandalism.—Dr. Adams Paulsen, director of the Meteorological Institute of Copenhagen, has gone to North Finland to study the aurora. He undertook a similar expedition last winter to North Iceland.—Prof. Baldwin Spencer and Mr. Gillen have arranged for another expedition in continuation of their investigations into the habits and folk-lore of the natives of Central Australia and the Northern Territory.